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LIQUID CRYSTAL DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a display apparatus using a liquid crystal display device, an
5 electroluminescence device, or the like. More particularly, it relates to a display apparatus having a light-source that is suitable for enhancing the luminance of the display screen with a high-efficiency and for making the luminance uniform on the display
10 screen.

DESCRIPTION OF THE RELATED ART

The display apparatus, which uses the liquid crystal display device (which is also referred to as "liquid crystal display panel"), the electrolumines-
15 cence device (which, depending on a fluorescent material used, is classified into an organic-family and an inorganic-family and, hereinafter, is referred to as "EL device"), a field emission device (which, hereinafter, is referred to as "FE device"), or the
20 like, performs the image display. However, unlike the case of a Braun tube (which, hereinafter, is referred to as "CRT", i.e., "cathode ray tube"), the display apparatus performs the image display under a condition that there is provided no space for 2-dimensionally
25 scanning an electron beam on the back side of the

display screen. Accordingly, as compared with the CRT, these display apparatuses have characteristics of being thinner and lighter-weighted, operating with a lower power consumption, and so on. These display appara-

5 tuses, in some cases, are referred to as "flat panel displays" from the characteristics in their outward appearance.

From the above-described advantages over the CRT, the display apparatus using the liquid crystal

10 display device, the EL device, the FE device, or the like is becoming widely prevalent in various types of uses in substitution for a display apparatus using the CRT. In the background to this situation, there exist the technical innovations such as an enhancement in the

15 picture-quality of the liquid crystal display device, the EL device, or the like. Meanwhile, in recent years, the prevalence of the multimedia and the Internet has been increasing a demand for the motion-frame picture display. As a result, in the display

20 apparatus using the liquid crystal display device, improvements based on the liquid crystal material and the driving method are being made in order to implement the motion-frame picture display. Being not limited to the liquid crystal display apparatus, however, in the

25 display apparatuses referred to as the flat panel displays, the implementation of a higher luminance for displaying an image comparable to that of the conventional CRT has also become an important problem.

In order to obtain the image comparable to that of the conventional CRT, an impulse type light-emission is of absolute necessity. In the impulse type light-emission, each pixel is scanned with an electron

5 beam emitted from an electron gun, thereby causing a fluorescent substance in each pixel to perform the light-emission.

In contrast to this, the liquid crystal display apparatus, for example, employs a hold type

10 light-emission where a light-source unit including a fluorescent lamp is used. On account of this, it has been regarded as difficult for the display apparatus to implement the complete motion-frame picture display.

SUMMARY OF THE INVENTION

15 As the technology for solving the above-described problems related to the liquid crystal display apparatus, the following has been reported: A method of making improvements in the liquid crystal material or in the display mode of liquid crystal cells

20 (i.e., a liquid crystal layer sealed between the boards), and of using a directly-under type light-source unit (i.e., a light-source structure where a plurality of fluorescent lamps are located in a manner of being opposed to the display screen of the liquid

25 crystal display device) as the light-source. FIG. 16 is a diagram for illustrating the result that the present inventor has obtained by analyzing an example

of a lighting-up operation method for the directly-
under type light-source unit, the example having been
proposed for the motion-frame picture display. The
diagram illustrates the layout of the directly-under

5   type light-source unit where 8 tube-shaped fluorescent
lamps are located in a manner of being opposed to the
display screen (the dashed-line frame), and, as the
luminance waveforms, timings of the respective
lighting-up starting times for the respective lamps.

10   The luminance waveforms illustrated in FIG. 16 indicate
that the luminances are enhanced when the luminance
waveforms become convex in an upward direction in the
drawing. As clearly seen from FIG. 16, the lighting-up
starting times for the respective fluorescent tubes are

15   shifted in sequence from the starting times located on
the upper side to the starting times located on the
lower side. This sequential lighting-up operation,
which is synchronized with a scanning period of an
image display signal, has been repeated on the basis of

20   a 1-frame image display time-period (i.e., a time-
period during which the display signal is transferred
to all the pixels on the display screen). (Refer to
"Liquid Crystal", Vol. 3, No. 2 (1999), pp. 99-106).

On the other hand, there exists a technology

25   by which the luminance of the light-source is modulated
in correspondence with the scene of a motion-frame
picture signal transmitted to the liquid crystal
display apparatus. This technology allows the follow-

ing operation: Reading out maximum luminance data, minimum luminance data, and average luminance data of the display signal transmitted to the liquid crystal display apparatus for each image included in the

5 motion-frame picture signal, and, in correspondence with these data, controlling an electric current (hereinafter, referred to as "lamp current") that is to be fed to the light-source. Assuming that the lamp current is usually equal to a reference current (e.g.,

10 4.5 mA), in the case of an image that is bright as a whole, the lamp current is set to be higher (e.g., 8 mA) than the reference current during a certain time-period, afterwards being restored back to the reference current. Conversely, in the case of an image that is

15 dark as a whole, the lamp current is set to be lower (e.g., 1.5 mA) than the reference current. (Refer to "Nikkei Electronics", No. 757, September 15, 1999, pp. 139-146).

This setting, in the former case (i.e., the

20 image that is bright as a whole), feeds to the light-source the lamp current that is higher than the refer-ence current, thereby resulting in a temperature increase in the light-source which is larger by the amount of feeding the higher lamp current. In the case

25 of the fluorescent lamps, the temperature increase raises the mercury (Hg) vapor pressures inside the fluorescent lamps, thereby increasing the number of mercury atoms (i.e., mercury vapor quantity) inside the

fluorescent lamps. Meanwhile, if there exist surplus mercury atoms inside the fluorescent lamps, the surplus mercury atoms heighten a probability that ultraviolet rays generated inside the fluorescent lamps by the

5 collision between the mercury atoms and the electrons are absorbed into the mercury atoms, eventually decreasing the luminances of the fluorescent lamps themselves. In order to avoid this influence, after having set the lamp current to be higher than the

10 above-described reference current during the above-described time-period, the lamp current is restored back to the reference current before the mercury vapor pressures inside the fluorescent lamps are altered. Changing the lamp current in this way makes the

15 luminances of the fluorescent lamps higher than those of the fluorescent lamps at the time when the reference current is fed thereto. Also, in the latter case (i.e., the image that is dark as a whole), if the luminance of the light-source is high, it becomes

20 required to suppress a slight leakage of the light from a pixel displaying black or a color close thereto. On the screen that is dark as a whole, even in a pixel the light-transmittance of which is set to be the highest within the screen, the absolute quantity of the light

25 to be transmitted is small. On account of this, the lamp current is set to be lower than the reference current, thereby suppressing the luminance of the light-source so as to throttle the leakage of the light

from the pixel displaying black or the color close
thereto, and at the same time reducing the power
consumption in the light-source.

From the combination of these two technolo-
5 gies, the dynamic range (i.e., the ratio of the maximum
luminance/the minimum luminance) of the luminance in an
image viewed in all the motion-frame pictures can be
expanded up to 2.8 times as wide as the conventional
dynamic range. Moreover, the contrast ratio thereof
10 can be expanded up to 400 ~ 500 : 1, which is more than
2 times as high as that of the conventional liquid
crystal display apparatus.

When the above-described technology of
performing in sequence the lighting-up operation for
15 the directly-under type light-source unit is executed
in the liquid crystal display apparatus, for example,
the number of the fluorescent lamps mounted on the
directly-under type light-source unit is increased.
This attempt shortens the light-emission times of the
20 respective fluorescent lamps which are occupied during
a 1-period (which is equivalent to the amount of 1
frame) lighting-up operation time-period. This
eventually decreases the luminance efficiency of the
directly-under type light-source unit as a whole.

25   Also, if the electric powers applied to the
respective fluorescent lamps are increased in order to
heighten the luminance of a displayed image, the
resultant fever by the fluorescent lamps locally heats

the liquid crystal cells, thereby reducing the uniformity as well.

The image display in the liquid crystal display apparatus is executed as follows: Liquid crystal molecules that are sealed into the liquid crystal cells of the liquid crystal display device mounted on the display apparatus are orientated in a direction corresponding to the image information (i.e., an electric field applied to the liquid crystal cells) so as to set the light-transmittances of the liquid crystal cells to be a desired value. For this purpose, it is desirable to maintain the viscosity within the liquid crystal cells at a proper value so that the liquid crystal molecules in the liquid crystal cells are securely orientated in the direction corresponding to the image information. Here, in some cases, a viscosity-increasing agent or a viscosity-decreasing agent, together with the liquid crystal molecules, is sealed into the liquid crystal cells. If, however, the temperatures of the liquid crystal cells are increased locally, the viscosity is lowered at this section. On account of this, the directions of a portion of the liquid crystal cells become random (equal-directing of the liquid crystal layer).

Consequently, only the liquid crystal cells at this section exhibit the light-transmittances not corresponding to the electric field applied to the liquid crystal molecules. This condition makes it

difficult to raise, up to 300 cd/m^2 or higher, the display luminance by a transverse electric-field type liquid crystal display apparatus.

Also, when the above-described technology of
5   adjusting the luminance of the light-source for each image included in the motion-frame picture signal is executed toward the liquid crystal display apparatus, from a practical standpoint, it is difficult to set the timing with which the lamp current, which is fed to the
10   light-source at the time of displaying the image that is bright as a whole, is lowered from the value higher than the above-described reference current down to the reference current. As having been described earlier, in order to make the luminance of the light-source
15   higher than the value at the time when the reference current is fed to the light-source, the lamp current that has been once set to be higher than the reference current must be restored back to the reference current before the mercury vapor pressures inside the fluores-
20   cent lamps are altered. However, the timing with which the lamp current is switched in this manner cannot help being set empirically in accordance with, for example, the correlation between measurement data of the temperature increase in the light-source (i.e., the
25   fluorescent lamps) and the luminance of the light-source. Also, if the usage conditions for the display apparatus the examples of which include even a differ-ence in the room temperature or the like should be

taken into consideration, it is extremely difficult to set the timing with which the lamp current is switched. Furthermore, in this technology, since the light-source luminance at each image display point-in-time is

5   changed in response to the brightness of each image, the contrast ratio for each image remains at an order that the conventional liquid crystal display apparatus makes it possible to accomplish. This, in other words, means the following: Even if this technology is

10 applied to the liquid crystal display apparatus, when displaying an image the brightness of which remains almost unchanged over a certain fixed time-period (i.e., a time-period during which display data of a plurality of frames is transferred to the liquid

15 crystal display apparatus), it is difficult to enhance the contrast ratio thereof.

It is an object of the present invention to provide a liquid crystal display apparatus and a control method therefor, the liquid crystal display

20 apparatus enhancing the luminance of a displayed image with a high-efficiency and suppressing the heat-liberation of the light-source.

Also, it is another object of the present invention to provide a liquid crystal display apparatus

25 that improves a blur in a motion-frame picture, and a control method therefor.

Also, it is still another object of the present invention to provide a liquid crystal display

apparatus that enhances the contrast ratio, and a control method therefor.

5 In order to accomplish the above-described objects, in the present invention, the following configuration is employed: In a liquid crystal display apparatus that includes a liquid crystal panel and a light-source provided onto the liquid crystal panel for illuminating the panel, the light-source has a period constituted by a 1st light-emission luminance and a 2nd

10 light-emission luminance, the time ratio of the 1st light-emission luminance and that of the 2nd light-emission luminance during the period being changed in accordance with display data supplied from the outside.

Here, the 1st light-emission luminance is

15 higher than the 2nd light-emission luminance. As one example thereof, the time ratio of the 1st light-emission luminance during the period is set to be 60 % or smaller when the display data is of motion-frame pictures, and is set to be 60 % or larger when the

20 display data is of freeze-frame pictures. Also, the 2nd light-emission luminance is set to be substantially 0, which is intended to enhance the reproducibility at the time when the afterimage and the luminance of the 2nd light-emission luminance are low.

25 Also, as one example of the controlling circuit configuration, the controlling circuit includes the following components: A data storing unit for storing the display data at least by the amount of 1

frame, a data comparing unit for comparing corresponding pixels between the display data stored in the data storing unit and the display data to be inputted, and a pulse controlling unit that, in correspondence with the

5 comparison result by the data comparing unit, outputs a signal for controlling the time ratio of the 1st light-emission luminance during the period.

Also, the present invention includes a liquid crystal display apparatus where the comparison pixels

10 compared by the data comparing unit have a distribution of being concentrated in a proximity to the center of a display unit of the above-described liquid crystal panel. Here, the proximity to the display unit may also be a region determined in advance. This region

15 may also be contained within a fixed-length of distance from a predetermined pixel.

Also, in order to make the liquid crystal display apparatus correspond to the plurality of light-sources, the controlling circuit is configured as

20 follows: The controlling circuit define to display panel with corresponding to each source light, and starting time of above-mentioned first luminous and second luminous luminance is organized that is able to change with according to display data supplying from

25 outside with according to display data with each fields.

As another example of the controlling circuit configuration, the controlling circuit includes the

following components: A luminance data generation

controlling unit for generating luminance data from the

respective image data of R, G, and B, a luminance

distribution detection controlling unit that, from the

5   generated luminance data, detects a luminance distribu-

tion state for the input image data by the amount of 1

frame, a folded-line point tone controlling unit for

controlling a tone characteristic in accordance with

the luminance distribution detection result, a back-

10   light light-dimmer controlling unit for performing a

light-dimmer control over a backlight in accordance

with the luminance distribution detection result, and a

blink backlight controlling unit for controlling a

light-emission timing of the backlight for the display

15   data by the amount of 1 frame.

Also, as still another example of the

controlling circuit configuration, it is also allowable

to employ a configuration that simultaneously has both

of the configurations presented by the above-described

20   two examples.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram for illustrat-

ing a liquid crystal display apparatus to which the

present invention is applied; FIG. 2 are diagrams for

25   illustrating luminance waveforms of a light-source and

so on in the liquid crystal display apparatus to which

the present invention is applied; FIGS. 3A and 3B are

diagrams for illustrating the structure of a liquid
crystal display apparatus using a sidelight type light-
source unit; FIGS. 4A and 4B are diagrams for illus-
trating the structure of a liquid crystal display

5   apparatus using a directly-under type light-source
unit; FIGS. 5A and 5B are diagrams for illustrating the
in-tube temperature of a cold-cathode ray tube and the
luminance characteristic toward a fed current; FIG. 6
is a diagram for illustrating the luminance response by

10   the light-source unit according to the present
invention; FIGS. 7A and 7B are diagrams for illustrat-
ing the elapsed-time change of the display luminance of
a liquid crystal display apparatus where a cold-cathode
ray tube is employed as the light-source, and the

15   elapsed-time change of the cold-cathode ray tube
temperature; FIG. 8 is a diagram for illustrating an
embodiment of a controlling circuit for executing a
blinking lighting-up of the light-source according to
the present invention; FIG. 9 is a diagram for illus-

20   trating an embodiment of the setting of a blinking
lighting-up ratio of the light-source according to the
present invention; FIG. 10 is a diagram for illustrat-
ing an embodiment of the setting of the blinking
lighting-up ratio of the light-source according to the

25   present invention; FIGS. 11A, 11B, and 11C are diagrams
for illustrating an embodiment of the setting of a
blinking lighting-up period of the light-source accord-
ing to the present invention; FIG. 12 is a diagram for

illustrating an embodiment of the setting of a pausing
time-period in the blinking lighting-up of the light-
source according to the present invention; FIGS. 13A
and 13B are diagrams for illustrating an embodiment of
5 the sidelight type light-source unit according to the
present invention; FIGS. 14A and 14B are diagrams for
illustrating the structure of the liquid crystal
display apparatus (i.e., a transverse electric-field
mode liquid crystal display apparatus) using the
10 sidelight type light-source unit according to the
present invention; FIG. 15 is a diagram for illustrat-
ing the layout of an inverter apparatus used in the
liquid crystal display apparatus illustrated in FIGS.
13A, 13B; FIG. 16 is a diagram for illustrating the
15 result that the present inventor has obtained by
analyzing the lighting-up operation method for the
directly-under type light-source unit that belongs to
the prior art; FIG. 17 is a diagram for illustrating
the configuration of a controlling circuit for the
20 sidelight type light-source unit according to the
present invention; FIG. 18 is a diagram for illustrat-
ing an example of a switching controlling circuit 25
illustrated in FIG. 17; FIG. 19 is a timing diagram of
a light-source lighting-up signal BL generated by the
25 switching controlling circuit 25 illustrated in FIG.
18; FIGS. 20A and 20B are comparison diagrams where the
conventional hold type light-emission is compared with
an impulse type light-emission according to the present

invention; FIG. 31 is a schematic configuration diagram of a liquid crystal display module according to another embodiment of the present invention; FIG. 32 is a schematic configuration diagram of a TCON board

5   implemented on the back surface of the liquid crystal display module according to the present invention; FIG. 33 is a schematic configuration diagram of the internal function of LSIs mounted on the TCON board according to the present invention; FIG. 34 is a specification

10   diagram of image data conversion (i.e., low-voltage differential $\rightarrow$ TTL, and TTL $\rightarrow$ low-voltage differential) input/output signals according to the present invention; FIG. 35 is a schematic timing diagram of the operation of a frame memory controlling unit according

15   to the present invention; FIG. 36 is a timing diagram of a driver interface according to the present invention; FIG. 37 is a timing diagram of a digital backlight light-dimmer signal according to the present invention; FIG. 38 is a conceptual diagram of the

20   operation of a luminance data generation controlling unit according to the present invention; FIG. 39 is a schematic configuration diagram of a luminance distribution detection controlling unit according to the present invention; FIG. 40 is a state transition

25   diagram for illustrating the operation of a luminance distribution detecting unit according to the present invention; FIG. 41 is a schematic diagram for showing a luminance distribution detection result obtained by the

invention; FIGS. 21A and 21B are diagrams for illus-
trating an embodiment of a detection point of the data
comparison in the present invention; FIG. 22 is a
diagram for illustrating an embodiment of the switching

5 controlling circuit 25 illustrated in FIG. 17; FIG. 23
is a diagram for illustrating a dividing method for a
display screen for explaining the switching controlling
circuit 25 illustrated in FIG. 22; FIG. 24 is a timing
diagram of a light-source lighting-up signal BL

10 generated by the switching controlling circuit 25
illustrated in FIG. 22; FIG. 25 is a diagram for illus-
trating the configuration of a controlling circuit for
the directly-under type light-source unit according to
the present invention; FIG. 26 is a diagram for

15 illustrating an embodiment of the switching controlling
circuit 25 illustrated in FIG. 25; FIG. 27 is a timing
diagram of light-source lighting-up signals BL 1 to BL
4 generated by the switching controlling circuit 25
illustrated in FIG. 26; FIG. 28 is a diagram for

20 illustrating a switching controlling circuit 25 for
implementing a light-source lighting-up control in
correspondence with the display luminance of a
displayed image according to the present invention;
FIG. 29 is a timing diagram of a light-source lighting-

25 up signal BL generated by the switching controlling
circuit 25 illustrated in FIG. 28; FIG. 30 is a diagram
for illustrating the configuration of a lighting-up
method instructing circuit 60 according to the present

luminance distribution detection controlling unit according to the present invention, and an arithmetic-calculation formula for calculating a luminance average value from the detection result; FIG. 42 is a state

5 transition diagram for illustrating the operation of another embodiment that differs from the embodiment illustrated in FIG. 40 of the luminance distribution detecting unit according to the present invention; FIG. 43 is a schematic diagram for showing a luminance

10 distribution detection result obtained by another embodiment that differs from the embodiment illustrated in FIG. 41 of the luminance distribution detection controlling unit according to the present invention, and an arithmetic-calculation formula for calculating a

15 luminance average value from the detection result; FIG. 44 is a diagram for illustrating the tone control by a folded-line point tone controlling unit according to the present invention; FIG. 45 is a schematic configuration diagram of the folded-line point tone control-

20 ling unit according to the present invention; FIG. 46 is a diagram for illustrating the tone control by another embodiment that differs from the embodiment illustrated in FIG. 44 of the folded-line point tone controlling unit according to the present invention;

25 FIG. 47 is a schematic configuration diagram of another embodiment that differs from the embodiment illustrated in FIG. 45 of the folded-line point tone controlling unit according to the present invention; FIG. 48

illustrates an example of a light-dimmer characteristic diagram in an inverter board according to the present invention; FIG. 49 illustrates an example of the luminance control and the motion-frame picture's blur improving control by a backlight light-dimmer controlling unit and a blink controlling unit according to the present invention; FIG. 50 illustrates an example of the image judgement based on the luminance distribution detection data according to the present invention; FIG. 51 illustrates an example of a state transition diagram of the light-dimmer control in accordance with an image judging condition's example according to the present invention; FIG. 52 illustrates an example of the luminance control and the motion-frame picture's blur improving control by another embodiments that differs from the embodiments illustrated in FIG. 49 of the backlight light-dimmer controlling unit and the blink controlling unit according to the present invention; FIG. 53 illustrates an example of the luminance control and the motion-frame picture's blur improving control by another embodiments that differs from the embodiments illustrated in FIGS. 49 and 52 of the backlight light-dimmer controlling unit and the blink controlling unit according to the present invention; FIG. 54 illustrates an example of the luminance control and the motion-frame picture's blur improving control by another embodiments that differs from the embodiments illustrated in FIGS. 49, 52 and 53 of the backlight

light-dimmer controlling unit and the blink controlling

unit according to the present invention; and FIG. 55

illustrates an example of the luminance control and the

motion-frame picture's blur improving control by

5　another embodiments that differs from the embodiments

illustrated in FIGS. 49, 52, 53 and 54 of the backlight

light-dimmer controlling unit and the blink controlling

unit according to the present invention.

DESCRIPTION OF THE EMBODIMENTS

10　　　　　The present invention includes a panel on

which a plurality of pixels are located, a light-source

for visualizing an image displayed on the plurality of

pixels, and a controlling circuit for controlling the

light-source. Here, during a 1st time-period, the

15　controlling circuit feeds the light-source an electric

current having a 1st intensity. During a 2nd time-

period, the controlling circuit feeds the light-source

an electric current having a 2nd intensity (which

differs from the 1st intensity). Also, the controlling

20　circuit repeats the 1st time-period and the 2nd time-

period periodically. Furthermore, the controlling

circuit controls the light-source so that the intensity

of a light emitted from the light-source in this period

(i.e., an integrated value obtained by integrating the

25　luminance of the light during this period) will become

higher than an integrated value of the luminance in the

case where the light-source is lit up by a rating

electric current during the same time-period.

Incidentally, concerning the integrated value of the

luminance in the case where the light-source is lit up

by the rating current, the luminance being in a stable

5   state in about 30 minutes after the lighting-up has

been employed as the target to be integrated.

Also, in the case where the display apparatus

is a liquid crystal display apparatus, the panel

includes a pair of boards (at least one of which has a

10   light-transmittance that is large enough to permit the

light from the light-source to pass) located in such a

manner as to be opposed to each other, and a liquid

crystal layer (i.e., liquid crystal molecules, or the

molecules including an additive agent such as a

15   viscosity-decreasing agent) sealed between the pair of

boards. Moreover, on at least one of the pair of

boards, there are provided electrodes included in the

pixels and signal lines for transferring image informa-

tion to the electrodes. The panel configured in this

20   manner is referred to as "liquid crystal display panel"

or "liquid crystal display element". In the light-

source, a fluorescent lamp or an optical element (e.g.,

a light-guiding plate) connected optically to the

fluorescent lamp is located on at least one plane of

25   the panel in a manner of being opposed thereto. In

recent years, there has been also proposed a light-

source using a light-emitting element array where,

instead of the fluorescent lamp, a plurality of light-

emitting elements are located along the panel. The present invention is applicable to a matrix type display apparatus. On account of this, the present invention is also applicable to a plasma display

5 apparatus.

In the display apparatus according to the present invention, the large-or-small relationship between the 1st and the 2nd electric currents that are fed to the light-source is not particularly specified.

10 However, as is the case with the conventional case, considering the case as well where the display apparatus is utilized under a condition of lighting up the light-source continuously, it is desirable to set the 2nd electric current to be smaller as compared with the

15 1st electric current.

Incidentally, in the liquid crystal display element, the luminance of an image to be displayed is calculated from an image-signal transferred to the display apparatus, and then the 1st and the 2nd current

20 values and the time sharing of the 1st and the 2nd time-periods may be adjusted in agreement with the calculated luminance (a viewpoint 1). In particular, with respect to image data the luminance or the contrast of which need not be enhanced, the value of,

25 especially, the larger one out of the 1st and the 2nd currents is suppressed, thereby saving the power consumption. In this case, even if the intensity of the light emitted from the light-source in the period

(i.e., the integrated value obtained by integrating the luminance of the light during the period) becomes lower than the integrated value of the luminance in the case where the light-source is lit up by the rating-current during the same time-period, this situation presents no problem.

Hereinafter, the explanation will be given concerning the concrete modes of the present invention, referring to the drawings related therewith.

In the drawings that will be referred to in the following explanation, the configuration components having the same function are designated by the same reference numerals, and the repeated explanation thereof will be omitted.

FIG. 1 is a schematic diagram for illustrating a liquid crystal display apparatus on which a liquid crystal display module according to the present invention is mounted. In FIG. 1, the reference numerals denote the following components, respectively: 8 a fluorescent lamp, 20 a direct voltage source input terminal, 21 an inverter circuit, 23 a light-dimmer circuit, 25 a switching controlling circuit, 27 a liquid crystal panel, 28 the liquid crystal display module, 29 a television input terminal, 30 a video input terminal, 31 an S input terminal, 32 an analogue PC input terminal, 33 a digital PC input terminal, 34 an analogue image processing controlling unit, 35 a digital image processing controlling unit,

and 36 the liquid crystal display apparatus.

In FIG. 1, the liquid crystal display apparatus 36 mainly allows a motion-frame picture from, as image inputs, the television input terminal 29, the

5 video input terminal 30, the S input terminal 31, and so on, and mainly allows a freeze-frame picture from the analogue PC input terminal 32, the digital PC input terminal 33, and so on. The analogue image processing controlling unit 34 subjects inputted analogue image

10 data to a luminance/color signal separation processing, an analogue/digital conversion processing, and so on, then outputting, as digital image data, the data to the digital image processing controlling unit 35. The digital image processing controlling unit 35 subjects

15 the digital image data to an interlace/non-interlace conversion processing, an expansion processing, and so on, then outputting the data to the liquid crystal display module 28. In the liquid crystal display module 28, the inputted digital image data (DATA) is

20 inputted into the switching controlling circuit 25 as well as into the liquid crystal panel 27. The switching controlling circuit 25 detects the state of this inputted digital image data (DATA). In addition, the switching controlling circuit 25 outputs a detection

25 signal, i.e., the detection result, to the light-dimmer circuit 23. In accordance with the state of this detection signal, the light-dimmer circuit 23 outputs to the inverter circuit 21 a light-dimmer controlling

signal for obtaining an excellent display state. This

allows the light-dimmer circuit 23 to perform a light-

source control over the fluorescent lamp 8.

Hereinafter, the explanation will be given in

5   sequence concerning the details of the respective

components.

FIGS. 3A and 4A are cross-sectional views for

conceptually illustrating the structures of the liquid

crystal panel. FIGS. 3B and 4B are perspective vies

10 for illustrating a light-source unit fixed onto the

liquid crystal display apparatus. In any one of the

drawings, the liquid crystal panel has a liquid crystal

display element and a light-source unit 10 where the

fluorescent lamp 8 is mounted. Here, the liquid

15 crystal display element includes a pair of boards 3 the

respective principal planes of which are located in a

manner of being opposed to each other, and a liquid

crystal layer 2 (i.e., liquid crystal molecules, or a

mixture of the molecules and a viscosity-decreasing

20 agent or the like are sealed) sandwiched between the

pair of boards. In FIGS. 3A and 4A, on the principal

planes of the boards 3, sheet polarizers 1 are provided

on the sides opposite to the liquid crystal layer 2.

Also, on at least one of the pair of boards 3, a

25 plurality of pixels (not illustrated) are located in a

2-dimensional manner on the principal plane on the side

of the liquid crystal layer 2. In the panel illus-

trated in either of FIGS. 3A and 4A, the user can see

an image from the above in the drawings through the
principal planes of the boards 3.

The liquid crystal panel illustrated in FIGS.
3A and 3B is referred to as "sidelight type" (or
5   "edgelight type") from the location of the fluorescent
lamp 8 in the light-source unit 10. The light-source
unit 10 includes the following components: A light-
guiding plate 11 having a quadrilateral-shaped upper
plane located in a manner of being opposed to a lower
10 plane of the above-described liquid crystal display
element, the tube-shaped fluorescent lamps 8 located
along at least one side plane (i.e., one side of the
quadrilateral) of the light-guiding plate, a reflector
7 by which a light emitted from the fluorescent lamp 8
15 onto the opposite side of the light-guiding plate is
launched into the side plane of the light-guiding
plate, and a reflection film 9 by which a light
propagating inside the light-guiding plate down toward
its lower plane is caused to be reflected up toward its
20 upper plane and is caused to illuminate the lower plane
of the liquid crystal display element. Between the
upper plane of the light-guiding plate 11 and the lower
plane of the liquid crystal display element, there is
located an optical sheet group 4 including a pair of
25 diffusion films 6 and a prism sheet 5 sandwiched
therebetween. In the sidelight type liquid crystal
panel, the lower plane of the liquid crystal display
element is located in such a manner that the lower

plane is opposed not to the fluorescent lamp 8 but to
the upper plane of the light-guiding plate 11 illus-
trated in FIG. 3B.

In contrast to this, the liquid crystal panel

5   illustrated in FIGS. 4A and 4B is referred to as
"directly-under type". This is named after the
location that a plurality of fluorescent lamps 8 in the
light-source unit 10 are located in a manner of being
opposed to the lower plane of the liquid crystal

10   display element (i.e., directly under the liquid
crystal panel as illustrated in FIGS. 4A). In the
light-source unit 10 used in the directly-under type
liquid crystal panel, reflectors 7 are located so that
lights emitted from the fluorescent lamps 8 down toward

15   the lower side in the drawing are reflected so as to
illuminate the upper side in the drawing (i.e., the
lower plane of the liquid crystal display element).
For this purpose, there are formed ups-and-downs for
eliminating variations in the light intensities in the

20   plurality of fluorescent lamps 8 and the clearances
therebetween. As is the case with the sidelight type
panel, an optical sheet group 4 is located between the
light-source unit 10 and the liquid crystal display
element. However, the diffusion sheets 6 located on

25   the side of the light-source unit 10 in the sidelight
type optical sheet group 4 have been replaced by a
diffusion plate 6a. In the diffusion plate 6a, there
is formed an optical pattern for eliminating the above-

described variations in the light intensities in the plurality of fluorescent lamps 8 and the clearances therebetween.

Additionally, the detailed explanation of the
5 sidelight type liquid crystal panel and that of the directly-under type liquid crystal panel have been given in, e.g., JP-A-7-281185 and JP-A-5-257142, respectively.

In the above-described liquid crystal panels,
10 increasing or decreasing an applied electric field to the liquid crystal layer 2 sets the light-transmittance, thus displaying an image. For example, in a TFT (i.e., thin film transistor)-driven liquid crystal display apparatus (active matrix type) of the
15 TN type or the vertical orientation type where the liquid crystal molecules are orientated at a twist angle of around 90°, or in a time-division-driven liquid crystal panel (passive matrix type) of the STN type where the molecules are orientated at a twist
20 angle of 200° to 260°, with an increase in the applied electric field to the liquid crystal layer 2, the light-transmittance changes from its maximum value (white image) to its minimum value (black image).

On the other hand, in a TFT-driven liquid
25 crystal panel referred to as the transverse electric-field type where the electric field to be applied to the liquid crystal layer 2 is applied in the direction along the board plane, with an increase in the applied

electric field to the liquid crystal layer 2, the light-transmittance changes from its minimum value (black image) to its maximum value (white image).

In the case of the TN type or the vertical

5   orientation type TFT-driven liquid crystal panel, as the value of Δnd which is the product of a refractive-index anisotropy Δn of the liquid crystal layer 2 and a cell gap (i.e., thickness of the liquid crystal layer 2) d, the range of 0.2 μm to 0.6 μm is desirable in

10   order to make the contrast ratio and the brightness compatible with each other. As the value of Δnd in the STN type liquid crystal panel, the range of 0.5 μm to 1.2 μm is preferable. As the value of Δnd in the transverse electric-field type TFT-driven liquid

15   crystal panel, the range of 0.2 μm to 0.5 μm is preferable.

Next, in accordance with the above-described viewpoint, the explanation will be given below concerning overviews of the aspects of the present invention

20   in the liquid crystal panels configured as described above.

FIG. 2 are diagrams for illustrating a synchronization signal (i.e., a transferring timing of image information), an image display signal, a

25   lighting-up signal of the light-source, and a luminance waveform of a light emitted from the light-source unit at the time when the present invention based on the viewpoint 1 is carried out toward the liquid crystal

display apparatus. The light-source lighting-up signal

is represented as a waveform indicating the following

operation: The 1st electric current i^I is fed to the

light-source during a time of Δt^I (i.e., the 1st time-

5 period), and then the 2nd electric current i^{II} smaller

than the 1st electric current is fed to the light-

source during a time of Δt^{II} (i.e., the 2nd time-

period), and an operation period of $\Delta t^I + \Delta t^{II}$, i.e., a

summation of these two times, is repeated. In this

10 example, Δt^I and Δt^{II} have been set to be equal to each

other. Namely, the electric currents are fed to the

light-source with the duty of 50 %, and the value of

the 2nd electric current i^{II} is suppressed down to

substantially 0 mA. Accordingly, assuming that a

15 constant electric current is fed to the light-source

with an electric power that the light-source consumes

in the above-described operation period, it turns out

that the electric current value is illustrated as an

intermediate value i^{const} between the 1st electric

20 current and the 2nd electric current.

Furthermore, the luminance waveform of the

light-source makes it possible to predict that the

luminance corresponding to i^{const} will be equivalent to

an intermediate value I^{const} (a dashed line) between a

25 luminance I^I corresponding to the 1st electric current

(i.e., a value that the luminance reaches by the feeding

of the 1st electric current during the predetermined

time) and a luminance I^{II} corresponding to the 2nd

electric current (i.e., a value that the luminance
reaches by the feeding of the 2nd electric current
during the predetermined time). However, the
continuous feeding of the current i^{const} in a time
5   equivalent to the plurality of operation periods
gradually raises the light-source temperature, thereby
resulting in a gradual increase in the light loss
inside the light-source. On account of this, actually,
the luminance of the light-source exhibits a value
10 $I^{const'}$ (a solid line) that is lower than I^{const} (the
dashed line). Also, the temperature increase in the
light-source with the lapse of time gradually expands,
from ΔI^1 to ΔI^2, the difference between I^{const} (the
dashed line) and $I^{const'}$ (the solid line).
15   In contrast to this, if the time of Δt^I
during which the 1st current i^I is fed to the light-
source is set to be shorter than a turnaround time
during which the temperature increase in the light-
source caused by the 1st current i^I reaches a certain
20 value, it becomes possible to extract, without the
light loss inside the light-source, the light of the
luminance corresponding to the 1st current i^I. FIGS.
5A and 5B relate to a cold-cathode ray tube employed as
one example of the light-source. FIG. 5A indicates the
25 relationship between the in-tube temperature (which can
be regarded as being equivalent to the in-tube mercury
vapor pressure as well) and the luminance. FIG. 5B
indicates the relationship between the luminance and a

current fed to a pair of electrodes provided in the
cold-cathode ray tube. The luminance of the cold-
cathode ray tube depends on the in-tube mercury vapor
pressure, in other words, the quantity of the mercury

5   gas existing inside the tube. When the mercury gas
quantity is smaller than a certain value (which, in
this example, is equal to 4.7 Pa in terms of the
mercury vapor pressure), an increase in the mercury gas
quantity brings about an increase in the in-tube

10 temperature, thereby raising the luminance of the cold-
cathode ray tube itself as well. If, however, the
mercury gas quantity exceeds the certain value, the
mercury gas gradually absorbs the light generated
inside the tube, eventually resulting in a decrease in

15 the luminance of the cold-cathode ray tube as well.
The tendency like this, being not limited to the cold-
cathode ray tube and the mercury gas, can be recognized
as long as the tube sphere contains an excitation
material therein. The phenomenon similar to that in

20 the cold-cathode ray tube occurs also in, for example,
a xenon lamp.

Also, the mercury vapor pressure inside the
cold-cathode ray tube can be regarded as being
equivalent to the temperature inside the cold-cathode

25 ray tube as well. Moreover, the temperature inside the
cold-cathode ray tube is raised in response to the
current fed between the pair of electrodes provided in
the cold-cathode ray tube. Consequently, when continu-

ously feeding the current to the cold-cathode ray tube, the rise in the luminance is saturated in response to the rise in the current value, and thus the luminance will be saturated at a certain value (Refer to FIG.

5   5B).

However, as illustrated in the luminance waveform of the light-source in the 1st time-period Δt^I in FIG. 2, the feeding of the current i^I to the cold-cathode ray tube raises its luminance gradually. This

10 fact clearly shows that the rise in the in-tube temper-ature at the time of feeding a predetermined current to the cold-cathode ray tube occurs with a certain accompanying delay with respect to a feeding starting point-in-time of the current i^I. Moreover, considering

15 a rewriting period of the image data signal in the liquid crystal display apparatus, it is desirable to set the above-described operation period of the light-source to be smaller than this period. This period is equal to, e.g., 16.7 ms (ms = milliseconds) at 60 Hz,

20 and 8.4 ms at 120 Hz (these values are preferable for the motion-frame picture display). It is desirable to set the above-described operation period of the light-source to be smaller than these periods. However, by setting the above-described time sharing of the 1st and

25 the 2nd time-periods and the above-described 1st and the 2nd currents in correspondence with this operation period, it is possible to reduce the influence of the above-described temperature rise. From the catalogue

of the respective cold-cathode ray tubes referred to
earlier, when lighting up the cold-cathode ray tube
continuously with the rating current thereof (an
example of its value: 6 mA), the following findings can

5   be obtained depending on the surrounding temperature of
the cold-cathode ray tube:

(1) At a surrounding temperature of 40°C,
the luminance is saturated in about 150 seconds from
the starting of the lighting-up, and a decrease in the

10   luminance is unobserved even after the lapse of 200
seconds.

(2) At a surrounding temperature of 60°C,
the luminance exhibits its maximum value in about 15
seconds from the starting of the lighting-up, and after

15   that, the luminance is decreased slowly and attains to
90 % of its maximum value after the lapse of 200
seconds.

(3) At a surrounding temperature of 80°C,
the luminance exhibits its maximum value in about 10

20   seconds from the starting of the lighting-up, and for
about 10 seconds after that, the luminance is rapidly
decreased down to 80 % of its maximum value, and
thereinafter, the luminance is decreased slowly until
after the lapse of 200 seconds from the starting of the

25   lighting-up.

Based on these findings, the present inventor
has thought of the following idea and has confirmed its
effect: Even if the 1st current has been set to be

substantially 2 times as large as the rating current of
the cold-cathode ray tube, the value of the 2nd
current, which is set to be smaller as compared with
the 1st current, and its feeding time (i.e., the 2nd

5   time-period) are adjusted. This operation makes it
possible to prevent the temperature rise in the cold-
cathode ray tube.

Meanwhile, in the 2nd time-period, since the
2nd current smaller than the 1st current is fed to the

10   light-source, the luminance of the light-source is
decreased. However, when seen from the point-of-view
of a luminance of the light that has passed through the
liquid crystal display element (hereinafter, this
luminance is referred to as "panel luminance"), the

15   influence of the luminance decrease in the 2nd time-
period is unexpectedly small. Having made the
comparison with the use of an integrated value of the
panel luminance in the above-described operation period
(the duty: 50 %) by the amount of $\Delta t^{I} + \Delta t^{II}$ at the time

20   when the 2nd current is set to be 0 mA, concerning
afterglow of the light-source which occur in the 2nd
time-period, the following findings have been obtained
experimentally (Refer to FIG. 6):

(4) When a pixel of the liquid crystal

25   display element is white-displayed (i.e., an image-
signal that makes the light-transmittance of this pixel
its maximum value is sent to this pixel), the attenua-
tion of the light that has passed through the pixel is

smaller than having been expected. Moreover, an integrated value of the display luminance has become larger than the value at the time when the light-source is continuously lit up with the same electric power in

5 the above-described operation period.

(5) When a pixel of the liquid crystal display element is black-displayed (i.e., an image-signal that makes the light-transmittance of this pixel its minimum value is sent to this pixel), the attenua-

10 tion of the light that has passed through the pixel is sufficiently large. Moreover, an integrated value of the display luminance has been suppressed down to about one-half of the value at the time when the light-source is continuously lit up with the same electric power in

15 the above-described operation period.

Being not limited to the liquid crystal display apparatus, the maximum luminance required for the display apparatus turns out to become the luminance of a pixel displayed brightest (i.e., in white) out of

20 a plurality of pixels. In the other pixels, in particular, in a pixel displayed darkest (i.e., in black) or a pixel displayed in a tone close thereto (i.e., in dark gray), if the display luminances thereof are increased, the entire display screen becomes a

25 whitish image. The user of the liquid crystal display apparatus regards this whitish image as looking inferior to the image by the CRT.

However, the above-described findings (4) and

(5) that the present inventor et al. have obtained
experimentally have proved the following: In
comparison with the conventional method of feeding the
current continuously, as described above, the modula-
tion of the current fed to the light-source with the
predetermined duty makes it possible to enhance the
luminance of the pixel displayed brightest on the
display screen and, conversely, makes it possible to
suppress the luminance of the pixel displayed darkest.
Furthermore, the findings (4) and (5) have proved the
following: When the power consumptions in the above-
described duty are made equal to each other, as
compared with the case of lighting up the light-source
continuously, the above-described maximum luminance is
enhanced tremendously.

Although the grounds for this phenomenon have
not been elucidated completely, the experimental
results have clearly demonstrated the following: In
the pixel where the light-transmittance is set to be a
fixed height or more, the afterglow of the light-source
in the time-period during which the current vales is
suppressed (i.e., the above-described 2nd time-period)
has maintained its luminance more than expected. The
consideration given so far clearly proves that the
present invention can accomplish the object and the
other objects described already.

Incidentally, the findings (4) and (5) have
been derived from the result of a spectrum intensity

obtained as follows: The panel luminance sensitivity
of the liquid crystal display apparatus is measured in
compliance with the conditions stipulated in ED-2522 of
EIAJ (Standards of Electronic & Mechanical Industries

5 Association of Japan), and the spectrum intensity for
each wavelength in the visible-light area (i.e., 380 nm
~ 780 nm) is obtained by subjecting the panel luminance
to a luminous efficiency correction (i.e., converting
the panel luminance into a light amount that the human

10 eyes actually percept). This measurement is executed
under a condition that the liquid crystal display
apparatus is placed in a darkroom and a luminance meter
is set 50 cm apart from the liquid crystal display
element and is located perpendicularly to the display

15 region. As the luminance meter that is preferable for
executing such a measurement, there exists, e.g., the
PR704 type manufactured by Photo Research Corp. This
apparatus allows the luminance to be determined as the
value of a per-unit solid angle light-flux that does

20 not depend on the measurement distance or the measure-
ment area. This apparatus also makes it possible to
measure the following, respectively: The integrated
value of the luminance in a desired time, e.g., the
above-described operation period by the amount of $\Delta t^{I} +$

25 Δt^{II}, a variation in the luminance during the time, and
a luminance distribution of the liquid crystal display
element within the display screen. Additionally,
generally speaking, the contrast ratio described

previously can be determined from the ratio of "a luminance at the time when the entire display screen is white-displayed/a luminance at the time when the entire display screen is black-displayed". Instead of using

5 this general method, the contrast ratio may also be determined in the following way:

(1) A portion of the display screen (i.e., the pixels forming an image) is caused to be white-displayed (by sending, to the pixels, an image-signal

10 that makes the light-transmittances of the pixels their maximum values).

(2) A test pattern that causes another portion of the display screen (i.e., the pixels forming the image) to be black-displayed (i.e., sends, to the

15 pixels, an image-signal that makes the light-transmittances of the pixels their minimum values) is displayed on the liquid crystal display element.

(3) Calculating the luminance of the white-displayed portion and that of the black-displayed

20 portion (at this time, the respective display regions are assumed to be the same in size), the contrast ratio is determined as the luminance ratio therebetween.

In applying the present invention based on the viewpoint 1 to the liquid crystal display

25 apparatus, when the above-described operation period of the light-source is set to be smaller than the rewriting period (i.e., 16.7 ms at 60 Hz, 8.4 ms at 120 Hz) of the image data signal in the liquid crystal display

apparatus, it is desirable to dispense the liquid

crystal material (i.e., the liquid crystal layer) used

therein so that a response time of the liquid crystal

material will be suppressed shorter than the rewriting

5   period (the above-described 16.7 ms at 60 Hz or 8.4 ms

at 120 Hz) of the data signal. However, if, as

compared with the rewriting period of the data signal,

the response time of the liquid crystal material is

exceedingly slower by the amount of a predetermined

10   time, there occurs a ghost phenomenon (i.e., a multiple

profile). On account of this, it is more desirable to

shift a timing of the rewriting period of the image

data signal from that of the above-described operation

period of the light-source.

15   Consequently, it is advisable to make the two

timings different by establishing a predetermined phase

difference between the operation period, which includes

the 1st time-period Δt^{I} and the 2nd time-period Δt^{II}

illustrated in FIG. 2, and the rewriting period of the

20   image data signal (i.e., the period of the synchro-

nization signal Vsync illustrated in FIG. 2).

So far, the explanation has been given

regarding the modes of the present invention. Next,

based on the following embodiments, the explanation

25   will be added below regarding the further details.

<Embodiment 1>

In the present embodiment, the sidelight type

liquid crystal apparatus illustrated in FIGS. 3A and 3B

is configured using the pair of glass boards 3 that are
0.7 mm thick, and a thin film transistor for the TFT
driving is formed for each pixel on one of the boards.
Concerning the liquid crystal layer 2 sandwiched

5 between the pair of boards 3, the dielectric constant
anisotropy $\Delta n\varepsilon$ is set to be positive and Δnd is set
to be 0.41 μm. Also, although the twist angle of the
liquid crystal molecules sealed in the liquid crystal
layer 2 is made equal to 90°, lowering the twist angle

10 down to, e.g., 70°, is desirable in order to make the
liquid crystal response-rate faster. In the case of
suppressing the twist angle, Δnd that is appropriate
therefor becomes even smaller (e.g., 0.35 μm), and
accordingly shortening the cell gap is necessary.

15   The light-source unit 10 used in the present
embodiment is of the configuration wherein, as illus-
trated in the perspective view in FIG. 3B, the one
fluorescent lamp (the cold-cathode ray tube) 8 that is
4 mmϕ in outer diameter is located each in the long-

20 side direction of the light-guiding plate 11, i.e., the
two fluorescent lamps in total. Although not illus-
trated in the drawing here, the following components
may also be located: The diffusion sheet for enhancing
the luminance, a recursive polarization reflection

25 film, and a lens sheet for controlling the angle
dependence of an emitted light.

        In the present embodiment, with the above-
described 1st current and 2nd current set to be 10 mA

and 0 mA, respectively, the 1st and the 2nd currents
are fed to the fluorescent lamps 8 with the duty of
50 %. As illustrated in FIG. 7A, the surface tempera-
ture of the fluorescent lamps 8 is raised with the

5   lapse of time. In the meantime, as illustrated in FIG.
7A, the luminance is raised with time and, after that,
is attenuated temporarily, then being saturated soon.

Setting the duty to be 50 % or less in this
way makes the following possible: The temperature

10 rises in the central portions of the fluorescent lamps
8 are suppressed down to 70°C or less. Also, the
difference between a maximum value and a minimum value
of the luminances in the display region (i.e., effec-
tive display region) of the liquid crystal display

15 element (liquid crystal display panel) becomes equal to
more than 20 % as large as the average value there-
between. Also, even if the duty is suppressed down to
50 % or less, the maximum value of the luminance is
made equal to 200 cd/m^2 or more, and the minimum value

20 of the luminance is suppressed down to 2 cd/m^2 or less.

By the way, the lamp diameter of the fluores-
cent lamps used in the light-source unit is usually
about 2.6 mm, it is also possible to use a 3 mm
diameter type having an increased glass thickness, and

25 a 4 mm or more diameter type having an even thicker
inner diameter and increased containing quantities of
the gas and the mercury. In general, the lamp surface
area becomes larger as the lamp diameter is increased,

which is advantageous to the heat-dissipation.

Furthermore, there also exist effects such as a lower-

ing in the lighting-up voltage and an extension of the

lamp life-span (i.e., luminance half-value). Also,

5 when using the cold-cathode ray tube (the fluorescent

lamp) that is 2.6 mm in diameter (outer diameter),

applying the tube current of 6 mA or more regardless of

the length thereof results in the heat-liberation,

which lowers the light-emission efficiency (i.e., the

10 luminance). In contrast to this, in the present

embodiment, the outer diameter of the fluorescent lamps

8 is enlarged, thereby suppressing the influence of the

heat-liberation. This has also enhanced a discharge

efficiency by the fed current inside the fluorescent

15 lamps, thereby making it possible to obtain a suffi-

cient luminance even if the duty is suppressed down to

50 % or lower.

In the present embodiment, using a light-

dimmer circuit illustrated in FIG. 8, it is allowable

20 to set the ratio change of the above-described 1st

time-period (i.e., the lighting-up time-period) or that

of the above-described 2nd time-period (i.e., the

pausing time-period) during the above-described

lighting-up period of the light-source, and the change

25 in the applied voltage for lighting up the lamps of the

light-source, or it is also allowable to perform these

settings simultaneously. In the light-dimmer in the

lighting-up period (i.e., as illustrated in light-

source luminance waveform signals in FIG. 9, the light-
dimmer based on the ratio change of the lighting-up
time-period or that of the pausing time-period), it is
also possible to set the above-described lighting-up

5 period to be either of the lighting-up time-period and
the pausing time-period. Accordingly, as illustrated
in FIG. 9, it is also possible to improve the light-
emission efficiency by always providing the pausing
time-period without fully lighting up the lamps in the

10 above-described lighting-up period of the light-source.
Also, as illustrated in FIG. 10, it is also allowable
to blink the lamps only when the high luminances are
obtained.

Additionally, in FIG. 9, the range of the

15 high luminance is defined as being 300 cd/m^2 or more,
the range of the immediate luminance is defined as
being 200 to 299 cd/m^2 including 200 to 250 cd/m^2, and
the range of the low luminance is defined as being 199
cd/m^2 or less including 100 cd/m^2.

20 <Embodiment 2>

Next, in this embodiment, the explanation
will be given below concerning a modulation lighting-up
of the light-source suitable for displaying the motion-
frame pictures.

25 In the liquid crystal display apparatus, in
order to obtain motion-frame picture display character-
istics that are comparable to those of the CRT, the
lighting-up in the light-source is switched from the

all-the-time lighting-up to the blinking lighting-up
that has the lighting-up time-period and the pausing
time-period, respectively. This makes it possible to
implement the impulse type light-emission such as the

5   CRT. At this time, as illustrated in the respective
drawings in FIG. 9, it is also possible to change the
period of the blinking while maintaining the data
rewriting period (i.e., the period of Vsync here) at a
constant value.

10   In this way, the impulse type light-emission
comparable to the CRT can also be implemented in the
liquid crystal display apparatus using the blinking
lighting-up light-source unit, thereby allowing the
motion-frame picture display to be implemented. In the

15   conventional light-source unit, since the fluorescent
lamps are always lit up (i.e., the continuous lighting-
up) regardless of whether the image-signal is of the
bright display or the dark display, the energy
efficiency has been worsened. In contrast to this, the

20   illumination light-quantity of the light-source is
controlled in compliance with the information amount of
the image-signal. This enhances the light-emission
efficiency of the fluorescent lamps, thereby making it
possible to implement a further luminance enhancement

25   based on the saving of the power consumption and the
suppression of the rise in the lamp temperature.
Namely, the illumination light-quantity of the light-
source is decreased when the image is dark, and the

illumination light-quantity is increased when the image

is bright. This makes it possible to control the

relationship between the luminance and the tone

characteristic, i.e., the so-called tone curve -

5   characteristic, in agreement with the brightness of the

background and the image-signal. In this way, the time

ratio of the above-described 1st time-period (i.e., the

lighting-up time-period) and that of the above-

described 2nd time-period (i.e., the pausing time-

10   period when the 2nd current is set to be 0 mA) are

changed in correspondence with the information on the

bright-or-dark of the image-signal, thereby controlling

the illumination light-quantity of the light-source.

        Also, the time ratio of the lighting-up time-

15   period and that of the pausing time-period are changed

in correspondence with the information amount about a

movement of the image-signal, i.e., the lighting-up

time-period is shortened when the movement is fast,

thereby allowing a more beautiful motion-frame picture

20   display. Namely, in agreement with the state of the

image-signal, when the movement is slow, the slowness

in the liquid crystal response-rate presents no

problem. Accordingly, frame frequencies of input/

output are made to coincide with each other, and the

25   lighting-up time-period and the pausing time-period of

the light-source, by being made to correspond to this

output frame frequency, are also controlled by the

output frame period (FIG. 11A). Next, when the

movement of the image-signal is faster as compared with
the above-described case, in order to improve (i.e.,
speed up) the liquid crystal response-rate, the output
frame frequency is made 2 times faster than the input

5   frame frequency so as to insert dummy data. The
lighting-up time-period and the pausing time-period of
the light-source, by being made to correspond to this,
are also controlled by the output frame period (FIG.
11B).

10   Moreover, when the movement of the image-
signal is faster as compared with the above-described
case, the output frame frequency is made 3 times faster
than the input frame frequency so as to insert more
amount of dummy data, thereby improving the response-

15   rate. The lighting-up time-period and the pausing
time-period of the light-source, by being made to
correspond to this, are also controlled by the output
frame period (FIG. 11C).

            At this time, it is advisable to perform the

20   control so that the effective value of the current
applied to the lamps for causing the light-source to
perform the light-emission during each lighting-up
period becomes substantially constant regardless of the
ratio of the above-described lighting-up time-period

25   and that of the above-described pausing time-period of
the light-source. Also, changing the current effective
value makes it possible to change the illumination
light-quantity of the light-source. Also, by setting

the luminance in the above-described pausing time-period not to be completely 0 but to be a certain constant luminance as illustrated in FIG. 12, it is possible to ensure a sufficient luminance even in the

5 case where the entire screen exhibits a high luminance. Here, it is desirable to shorten, to a certain extent, a time-period where the luminance in the pausing time-period is enhanced.

In order to implement a more complete motion-

10 frame picture display, it is required not only to cause the light-source unit to perform the impulse type light-emission but also to synchronize data scanning timings of the image-signal with timings of the blinking of the light-source as illustrated in FIG. 16. In

15 general, as the data scanning timings of the image-signal, there exist a vertical or a horizontal synchronization signal, a frame signal, a scanning line signal, and the like. The scanning periods and the blinking periods of these signals are made equal to

20 each other so as to synchronize the scanning timings. In such a case, although the use of the directly-under type light-source unit is desirable and exhibits the outstanding effect, the use of the sidelight type light-source unit is also possible by the up-and-down

25 division thereof.

In the up-and-down divided sidelight type light-source unit, when the above-described period including the lighting-up time-period and the pausing

time-period in the light-source is equal to the rewriting period of the displayed image-signal, and when there exist n signal scanning lines of the above-described display apparatus, the starting time of a

5 n/2th signal scanning may be synchronized with the lighting-up starting time of the light-source. Namely, the image-signal is synchronized with the blinking of the light-source at the center of the screen, thereby allowing the motion-frame picture display. Further-

10 more, when the period including the lighting-up time-period and the pausing time-period in the light-source is equal to the rewriting period of the displayed image-signal, and when there exist the n signal scan-ning lines of the above-described display apparatus,

15 the starting time of a n = 1st signal period may be delayed by a certain amount of time from the lighting-up starting time of the light-source. Here, when this delay time is set to be the starting time of the n/2th signal scanning, the result becomes the same as that in

20 the method described earlier.

Also, in implementing the motion-frame picture display, it is effective to set the pausing time-period of the light-source to be more than 1/20th as long as the lighting-up starting time, and to set

25 the luminance in the pausing time-period to be less than 90 % as high as the luminance in the lighting-up starting time.

In a liquid crystal display apparatus that

includes a liquid crystal panel including a pair of
opposed-located boards at least one of which has
electrodes and a liquid crystal layer sandwiched
between the boards, a controlling circuit for applying
5   to the above-described electrodes a voltage correspond-
ing to a displayed image-signal, and a light-source for
illuminating the liquid crystal panel, the following
configuration is required in order to obtain a much
more beautiful motion-frame picture display: The
10 light-source includes a lamp, a reflector for reflect-
ing a light emitted from the lamp, and a light-guiding
plate for guiding the reflected light to the liquid
crystal layer, the lamp being located in the length
direction of at least one side of a side plane of the
15 light-guiding plate, the light-source having a period
including a lighting-up time-period and a pausing time-
period, an illumination light-quantity of the light-
source being changed by a time ratio of the lighting-up
time-period and that of the pausing time-period during
20 the period and a voltage value for causing the light-
source to perform the light-emission. The light-source
unit in the display apparatus is referred to as the so-
called sidelight type, and the 1 lamp is, or the 2 or 3
lamps are used and located in the thickness direction.
25 Also, in what position of the 4 sides of the light-
guiding plate the lamp should be located is determined
by the luminance of the display apparatus and the
transmittances of the liquid crystal cells.

Although the 1 lamp is located along the long-side of the light-guiding plate in a high-transmittance liquid crystal such as the TN type liquid crystal, in order to obtain a higher luminance, the 1

5 lamp may be each located along the 2 long-sides, or the 1 lamp may be each located along the short-side. Besides, the lamps may not be a linearly straight-line type but be the L-character type or the ⊐-character type having winding points. In the IPS mode with a low

10 transmittance, the 2 or 3 lamps may be each located along the 2 long-sides.

In addition, in a liquid crystal display apparatus that includes a liquid crystal panel including a pair of opposed-located boards at least one of

15 which has electrodes and a liquid crystal layer sandwiched between the boards, a controlling circuit for applying to the above-described electrodes a voltage corresponding to a displayed image-signal, and a light-source for illuminating the liquid crystal

20 panel, employing the following configuration becomes required: The light-source includes a plurality of fluorescent lamps located directly under the effective display region of the liquid crystal panel, and a plurality of reflectors for reflecting lights from the

25 respective lamps. The light-source has a period including a lighting-up time-period and a pausing time-period. It is also required to change an illumination light-quantity of the light-source by a time ratio of

the lighting-up time-period and that of the pausing

time-period during the period and a voltage value for

causing the light-source to perform the light-emission.

This light-source unit is the directly-under type. The

5   number of the lamps is about 4 to 12 in the long-side

direction or about 4 to 20 in the short-side direction,

depending on the luminance and the screen size.

In the light-source unit, conventionally, the

lamps have been located outside the effective display

10   region of the liquid crystal panel. This is intended

to prevent the liquid crystal cells from being heated

by the heat-liberation of the lamps. The liquid

crystal has a property that the value of the refractive

index is varied by the temperature change and the

15   transmittance is varied accordingly. On account of

this, in the case of being heated locally, its partial

transmittance, i.e., the luminance or the brightness,

is varied, becoming the display unevenness. The light-

source unit of the present invention, however, exhibits

20   a less heat-liberation, thus making it unlikely that

such a display unevenness will occur. Accordingly, it

is possible to locate the lamps in the light-source

inside the display region as is the case with, e.g.,

the directly-under type. This also makes it possible

25   to reduce the outer configuration size of the display

apparatus.

As the lamps used in the light-source unit

explained so far, the following are available: A cold-

cathode fluorescent lamp, a hot-cathode fluorescent
lamp, a xenon lamp, or a vacuum fluorescent display
tube.   The cold-cathode fluorescent lamp has a
characteristic of exhibiting a less heat-liberation.

5   However, in order to perform the heat-dissipation more
effectively, enlarging the lamp surface area is
required, and it is advisable to set the light-source
lamp diameter to be 3 mm or more.   Also, setting the
glass thickness of the light-source lamp to be 1 mm or

10   more in order to increase the heat specific-gravity
results in a more effective heat-dissipation.   It is
also possible to thicken the light-source lamp diameter
and to replace an in-lamp contained gas by xenon.

Based on the explanation given so far, the

15   concrete configurations will be described below
concerning the liquid crystal module according to the
present invention.

FIGS. 13A and 13B illustrate an embodiment of
the light-source unit where one fluorescent lamp 8 is

20   each located along two long-sides of a light-guiding
plate 11.   FIG. 13A illustrates an inverter location
where one transformer lights up the one lamp.   Instead,
as illustrated in FIG. 13B, the one transformer is able
to light up the two lamps.   In this case, the reduction

25   in the component number leads to a cost saving.   Here,
the inverter, which is a generic term for a circuit for
lighting up the lamps, includes a converting circuit
for converting a direct voltage to an alternating

voltage, a current controlling circuit, a frequency
modulating circuit, a voltage raising current by the
transformer, and so on. Also, in addition to the
transformer, the use of a piezoelectric element is

5 possible.

FIGS. 14A and 14B illustrate an embodiment of
a liquid crystal panel including a transverse electric-
field mode liquid crystal display element where a
liquid crystal layer 2 has Δnd = 0.28 μm and is

10 parallel-oriented at the twist angle 0°, and an
electric field parallel to the board planes is applied
thereto. FIG. 14A illustrates a cross-sectional view
of the liquid crystal display apparatus. Also, FIG.
14B illustrates a perspective view of a light-source

15 unit 10 mounted thereon. The light-source unit 10 has
a sidelight type structure where 2×2, i.e., 4 in total,
cold-cathode ray tubes that are 4 mmϕ in diameter are
located in the long-side direction. Here, it is
desirable that the inverter location be of a configura-

20 tion where, as illustrated in FIG. 15, the one trans-
former lights up the two fluorescent lamps 8.
<Embodiment 3>

In this embodiment, the explanation will be
given below regarding a system for executing a control

25 over the blinking lighting-up of the light-source
suitable for the motion-frame picture display in
correspondence with the detection of the movement
amount.

As described earlier, in the liquid crystal

display apparatus, in order to obtain the motion-frame

picture display characteristics comparable to those of

the CRT, the light-source is switched from the all-the-

5   time lighting-up to the blinking lighting-up that has

the lighting-up time-period and the pausing time-

period, respectively. This makes it possible to

implement the impulse type light-emission such as the

CRT. The explanation will be given below concerning

10 the control over this blinking.

First, consider the case where, with respect

to the display region of the liquid crystal display

apparatus, the entire display region as a whole is

blinking-lit up simultaneously. Here, the explanation

15 will be given employing, as an example, the system

using a sidelight type light-source where one fluores-

cent lamp 8 is each located along two long-sides of the

display region. FIG. 17 illustrates the configuration

of a controlling circuit for the sidelight type light-

20 source, wherein the reference numerals denote the

following components: 20 an input terminal for feeding

a direct power-supply voltage from the liquid crystal

display apparatus itself, a television apparatus

mounting this thereon, or the like, 23 a light-dimmer

25 circuit for converting the power-supply voltage to a

direct voltage equivalent to a voltage to be applied to

the light-source, 21 an inverter circuit for convert-

ing the direct voltage to an alternating voltage, and

25 a switching controlling circuit for controlling the
time ratio of the above-described 1st time-period
(i.e., the lighting-up time-period) and that of the
above-described 2nd time-period (i.e., the pausing
5 time-period when the 2nd current is set to be 0 mA).

As described earlier, the time ratio of the
1st lighting-up luminance (i.e., the lighting-up time-
period) and that of the 2nd lighting-up luminance
(i.e., the pausing time-period in the present example)
10 are changed in correspondence with the information
amount about the movement of the image-signal, thereby
allowing the more beautiful motion-frame picture
display. Namely, as illustrated in FIGS. 11A, 11B, and
11C, the lighting-up time-period is made shorter when
15 the movement is fast and the lighting-up time-period is
made longer when the movement is slow, or the lighting-
up time-period is made shorter when the moving informa-
tion amount (i.e., the moving pixel number) over the
entire surface of the display region is large and the
20 lighting-up time-period is made longer when the moving
information amount is small, thereby allowing the more
beautiful motion-frame picture display. At this time,
the current effective value applied to the lamps for
causing the light-source to perform the light-emission
25 during each lighting-up period is changed in corre-
spondence with the ratio of the lighting-up time-period
and that of the pausing time-period of the light-
source. This changes the illumination light-quantity

of the light-source, thus making it possible to
stabilize the luminance level of the motion-frame
picture display. For example, the time-period in which
the 1st lighting-up luminance occupies the period

5   including the 1st lighting-up luminance and the 2nd
lighting-up luminance is changed in correspondence with
a ratio with which the moving pixel number occupies the
pixel number constituting the screen of the entire
display region by the display data. If, for example,

10   the ratio with which the moving pixel number occupies
the pixel number constituting the entire screen by the
display data is equal to 10 % or more over 3 frames,
the display data is judged to be of motion-frame
pictures, and the ratio of the 1st lighting-up

15   luminance is set to be 50 % or less. In the cases
other than the above, the display data is judged to be
of freeze-frame pictures, and the ratio of the 1st
lighting-up luminance is set to be 50 % or more.

            Referring to FIG. 18, an example of the

20   switching controlling circuit 25 will be explained
below. FIG. 18 illustrates the configuration of the
switching controlling circuit 25, wherein the reference
numerals denote the following components: 50 a data
storing unit (which, in this case, is a frame memory)

25   for storing display information (Data) by the amount of
1 frame and reading the information in the next frame,
52 a data comparing unit for comparing, on the basis of
the corresponding pixels, the present frame display

data (Data) with the previous frame display data

(Data') read from the data storing unit 50, 53 a pulse

controlling unit for fetching an output from the data

comparing unit 52 on the basis of the amount of 1

5   display region (i.e., the amount of 1 frame) so as to

generate a starting time p s of the 1st time-period

(i.e., the lighting-up time-period) of the light-source

lighting-up signal BL and a time pw of the 1st time-

period (the unit of ps and pw is assumed to be a

10 horizontal time-period that is equal to one period of

Hsync), 51 a line count unit for performing an

initialization by the vertical synchronization signal

Vsync so as to count the horizontal synchronization

signal Hsync, and 54 a pulse generating unit for

15 generating the light-source lighting-up signal BL by a

line count value outputted by the line count unit 51

and p s and pw outputted by the pulse controlling unit

53. Here, the data comparing unit 52 compares, on the

basis of 1 display pixel (which is synchronized with 1

20 clock of Dotck), the present frame display data (Data)

with the previous frame display data (Data') read from

the data storing unit 50. As a result of this, if both

of the display data are different from each other, the

display data are judged to be of the motion-frame

25 pictures and a motion-frame picture judgement signal is

outputted toward the 1 display pixel.

The pulse controlling unit 53 adds the

motion-frame picture judgement signals from the data

comparing unit 52 by the amount of 1 screen of the

display region so as to cut and classify the addition

result in a step-like manner, thereby distinguishing

the movement information amount of the motion-frame

5   pictures in the display region and setting the starting

time ps of the 1st time-period and the time pw of the

1st time-period. In the data comparison between the

adjacent frames, when the data that occupy a constant

or more ratio (50 % or more) with respect to the entire

10   display region which actually displays the image data

are in disagreement with each other, the moving infor-

mation amount is defined as being large. Also, when

the data that occupy the constant or less ratio are in

disagreement, the moving information amount is defined

15   as being small. Incidentally, the large-or-small of

the information amount may also be defined by the

comparison with a predetermined information amount.

Moreover, the definition of the agreement/disagreement

of the data is as follows: In the comparison of the

20   respective pixels, in the case of the data with

constant or more tones (e.g., 128 or more tones in the

case of 256 tones in total), the data are judged to be

in disagreement with each other. Also, in the case of

the data with the constant or less tones, the data are

25   judged to be in agreement. FIG. 19 illustrates a

timing diagram of the light-source lighting-up signal

BL generated by the switching controlling circuit 25

configured as described above. A notation (a) in FIG.

19 illustrates the light-source lighting-up signal BL
in the case where, as a result of the comparison by the
data comparing unit 52, almost no change has been
judged to exist (i.e., a display close to freeze-frame

5   pictures, as describe later, when comparing a pixel 1
frame previously with a corresponding pixel of input
data, the amount of the disagreement is found to be
10 % or less). A notation (b) in FIG. 19 illustrates
BL in the case of a few motion-frame pictures (when

10 comparing the pixel 1 frame previously with the
corresponding pixel of the input data, the amount of
the disagreement is found to be in the range of 10 % to
50 %) (when compared with (a), more of the movement
information amount exists in (b)). A notation (c) in

15 FIG. 19 illustrates BL in the case of many motion-frame
pictures (when comparing the pixel 1 frame previously
with the corresponding pixel of the input data, the
amount of the disagreement is found to be 50 % or
more).

20   In general, the response-rate of the liquid
crystal necessitates the 1-frame period or more.
Consequently, as illustrated in FIG. 20A, in the
conventional hold type all-the-time lighting-up of the
light-source, by the time the tone attains to a reach

25 step value to be implemented, a transition tone appears
in a state of becoming a display blur. In order to
improve this display blur, the lighting-up timings
based on the pulse-width and the phase of the light-

source are synchronized with timings in which the tone attains to the tone data to be reached. This makes it possible to suppress the display of the transition tone, thereby allowing an excellent motion-frame

5 picture display with a less blur.

Also, the above-described data storing units 50 are provided by the amount of a plurality of frames, thereby making it possible not only to execute the comparison between the adjacent frame data but also to

10 execute the motion-frame picture detection for the time-period of the plurality of frames. This makes it possible to grasp the tendency of the movement, thus allowing a more faithful motion-frame picture judgement.

15 In the switching controlling circuit 25 explained so far, the frame memory is provided as the data storing unit 50 so as to store the display data by the amount of arbitrary frames, thereby executing the data comparison concerning the display data by the

20 amount of arbitrary frames and generating the light-source lighting-up signal BL in correspondence with the comparison result. However, accompanying the display region's expansion (which means the display resolution here) of the liquid crystal display apparatus, the

25 memory capacity of the data storing unit 50 is increased. When the display region was small, the switching controlling circuit 25 could be implemented by a 1-chip of controlling circuit (i.e., LSI).

Because of this capacity increase, however, the switch-
ing controlling circuit 25 must become a circuit of a
2-chip or more of controlling circuit configuration
where the data storing unit 50 is externally attached

5   as the liquid crystal display region is expanded. This
becomes a problem not only from the cost side of the
controlling circuit but also from the implementation
side of the board components. Accordingly, instead of
the above-described method of storing the display data

10 in the entire display region by the amount of 1 frame,
the data storing unit 50 may also be formed into the
following register configuration: Data comparing
pixels (i.e., detection points) have been determined in
advance in the display region, and only the display

15 data on the pixels are stored. However, the total
number of the pixels to be compared, which is deter-
mined by a restriction on the controlling circuit size,
is required to be determined so that the total number
in the case of using the frame memory and that in the

20 case of being formed into the register configuration
become substantially the same result. Here, FIGS. 21A,
21B illustrate examples of the data comparing pixels
(i.e., the detection points). FIG. 21A illustrates the
case where the detection points are set uniformly over

25 the display region of the display screen. FIG. 21B
illustrates the case where the detection points are set
in a manner of being concentrated onto the center of
the screen. In the case of FIG. 21A where the points

are distributed uniformly, the point number that
becomes equal to a constant ratio with respect to the
entire display region which actually displays the
display data (for example, when the constant ratio is
5   set to be 10 %, if the actual display region includes
horizontal 1024 pixels×vertical 768 pixels, i.e.,
786432 pixels in total, the point number becomes equal
to its 10 %, i.e., 78643 pixels) is distributed
uniformly over the actual display region. Meanwhile,
10   in the case of FIG. 21B illustrating the central
distribution, the constant ratio point number (i.e.,
78643 pixels) is distributed more in the central
portion than in the peripheral portion over the display
region.

15   In the recent personal computers, the OS
(i.e., operating system) employing the Windows system
has become the mainstream, and thus the computers allow
a plurality of windows to be displayed on the screen.
In addition, since it can be considered that the window
20   being in use at present is often displayed in the
center of the screen, the setting of the detection
points in FIG. 21B becomes effective.

          In order to implement a more complete motion-
frame picture display, it is advisable not only to
25   cause the light-source unit to perform the impulse type
light-emission but also to synchronize the data scan-
ning timings of the image-signal with the timings of
the blinking of the light-source. In the present

embodiment, in the center of the screen, the data
scanning timings of the image-signal have been synchro-
nized with the timings of the blinking of the light-
source.   However, being not limited to this method, it

5   is also advisable to determine the lighting-up starting
time in correspondence with the image information of
the entire display region.   Referring to FIG. 22, an
example of the switching controlling circuit 25 for
implementing this method will be explained below.

10   A switching controlling circuit 25 illus-
trated in FIG. 22 is the same as the circuit explained
in FIG. 18, except for the location of a mode judging
unit 55 for dividing the display region into a
plurality of regions (e.g., dividing the display region

15   into 4 regions as illustrated in FIG. 23) so as to
judge in which region there exist many motion-frame
picture displays.   The data comparing unit 52 compares,
on the basis of 1 display pixel (which is synchronized
with 1 clock of Dotck), the present frame display data

20   (Data) with the previous frame display data (Data')
read from the data storing unit 50.   As a result of
this, if both of the display data are different from
each other, the display data are judged to be of the
motion-frame pictures and the motion-frame picture

25   judgement signal is outputted toward the 1 display
pixel.   The mode judging unit 55, as illustrated in
FIG. 23, divides the display region into the 4 regions
and adds the motion-frame picture judgement signals for

each region, then outputting, from this addition

result, a mode signal for indicating a region where

there exist the most motion-frame picture judgement

signals. Next, in accordance with the mode signal, the

5   pulse controlling unit 53 sets a starting time ps of

the 1st time-period and a time pw of the 1st time-

period. FIG. 24 illustrates an example of a timing

diagram of the light-source lighting-up signal BL

generated by the switching controlling circuit 25

10   configured as described above. A notation (a) in FIG.

24 illustrates the light-source lighting-up signal BL

at the time of a mode Y1 where, in the uppermost

portion Y1 within the divided display regions illus-

trated in FIG. 23, the most motion-frame pictures exist

15   in comparison with the other 3 regions. Namely, the

starting time ps of the 1st time-period and the time pw

of the 1st time-period are set so that the 2nd time-

period (i.e., the pausing time-period) will start

immediately after the writing of the display data in

20   this region Y1 has been terminated (i.e., the starting

time of a n/4th signal scanning when there exist n

signal scanning lines of the display apparatus).

Hereinafter, similarly, notations (b), (c)

and (d) in FIG. 24 illustrate the case where the 2nd

25   display region Y2 is in the mode, the case where the

3rd display region Y3 is in the mode, and the case

where the 4th display region Y4 is in the mode,

respectively.

Next, consider the case where the display region of the liquid crystal display apparatus is divided into a plurality of regions so as to blinking-light up the respective regions individually. Here,

5 since a system using the directly-under type light-source can be easily implemented, the explanation will be given below employing the system as an example. FIG. 25 illustrates the configuration of a controlling circuit for the directly-under type light-source. Four

10 fluorescent lamps 8 are provided, and inverters 21 for controlling the lamps are each prepared for the respective lamps, i.e., the four inverters 21 in total. The other reference numerals denote the starting components: 20 an input terminal for feeding a direct

15 power-supply voltage, 23 a light-dimmer circuit for converting the power-supply voltage to a direct voltage equivalent to a voltage to be applied to the light-source, and 25 a switching controlling circuit for controlling the time ratio of the above-described 1st

20 time-period (i.e., the lighting-up time-period) and that of the above-described 2nd time-period (i.e., the pausing time-period when the 2nd current is set to be 0 mA). FIG. 26 illustrates the configuration of the switching controlling circuit 25.

25 Since the directly-under type light-source is configured by the 4 fluorescent lamps 8, the display region is divided into 4 regions as is the case with the display region illustrated in FIG. 23. The

switching controlling circuit 25 generates and outputs
light-source lighting-up signals BL1 to BL4 for execut-
ing the control over the blinking lighting-up of the
respective fluorescent lamps 8. The data comparing

5   unit 52 compares, on the basis of 1 display pixel
(which is synchronized with 1 clock of Dotck), the
present frame display data (Data) with the previous
frame display data (Data') read from the data storing
unit 50. As a result of this, if both of the display

10   data are different from each other, the display data
are judged to be of the motion-frame pictures and the
motion-frame picture judgement signal is outputted
toward the 1 display pixel. The mode judging unit 55,
as illustrated in FIG. 23, divides the display region

15   into the 4 regions and adds the motion-frame picture
judgement signals for each region, then outputting,
from this addition result, the mode signal for
indicating a region where there exist the most motion-
frame picture judgement signals. The mode signal does

20   not simply select and indicate the 1 region where there
exist the most motion-frame picture judgement signals,
but also may indicate 2 or more regions, depending on
the display. Also, in the case of indicating the 2 or
more regions, it presents no problem whether the 2

25   regions are adjacent regions or dispersed regions. In
addition, it is possible to easily control the 2
regions by the large-or-small relationship in the
addition result of the per-region motion-frame picture

judgement signals outputted from the mode judging unit
55.

Next, in accordance with the mode signal, the
pulse controlling unit 53 sets starting times (i.e., ps
5 1 to ps 4) of the 1st time-period and times (i.e., pw 1
to pw 4) of the 1st time-period in the light-source
lighting-up signals BL1 to BL4 for the respective
display regions. Next, the pulse generating unit 54
generates the light-source lighting-up signals BL1 to
10 BL4 by the line count value outputted by the line count
unit 51 and ps 1 to ps 4 and pw 1 to pw 4 outputted by
the pulse controlling unit 53. FIG. 27 illustrates an
example of a timing diagram of the light-source
lighting-up signals BL1 to BL4 generated by the switch-
15 ing controlling circuit 25 configured as described
above. A notation (a) in FIG. 27 illustrates BL1 to
BL4 in the case where there exist a few motion-frame
displays (naturally, the case of freeze-frame pictures
is also included) or in the case where, even if there
20 exist motion-frame pictures to some extent, a differ-
ence in their total number cannot be detected for each
region (i.e., there exists no mode). Because there
exists no mode, an optimum setting is performed for
each region. Namely, in the region Y1, the starting
25 time ps 1 of the 1st time-period and the time pw 1 of
the 1st time-period are set so that the 2nd time-period
will start immediately after the writing of the display
data in this region Y1 has been terminated (i.e., the

starting time of a n/4th signal scanning when there exist n signal scanning lines of the display apparatus), thereby generating the light-source lighting-up signal BL1. Hereinafter, similarly, in the

5 region Y2, ps 2 and pw 2 are set so that the 2nd time-period will start immediately after the writing of the display data in this region Y2 has been terminated (i.e., the starting time of a 2n/4th signal scanning when there exist the n signal scanning lines of the

10 display apparatus), thereby generating BL2. In the region Y3, ps 3 and pw 3 are set so that the 2nd time-period will start immediately after the writing of the display data in this region Y3 has been terminated (i.e., the starting time of a 3n/4th signal scanning

15 when there exist the n signal scanning lines of the display apparatus), thereby generating BL3. In the region Y4, ps 4 and pw 4 are set so that the 2nd time-period will start immediately after the writing of the display data in this region Y4 has been terminated

20 (i.e., the starting time of a nth signal scanning when there exist the n signal scanning lines of the display apparatus), thereby generating BL4. A notation (b) in FIG. 27 illustrates BL1 to BL4 in the case where the most motion-frame picture judgement signals exist in

25 the region Y1 (i.e., the mode Y1). In order to optimize the motion-frame picture display in the region Y1, the lighting-up control over the light-source is executed under a condition that the other regions Y2 to

Y4 are synchronized with the region Y1. Namely, the
starting times ps 1 to ps 4 of the 1st time-period and
the times pw 1 to pw 4 of the 1st time-period are set
to be the same value so that the 2nd time-period will

5 start immediately after the writing of the display data
in the region Y1 has been terminated (i.e., the start-
ing time of a n/4th signal scanning when there exist
the n signal scanning lines of the display apparatus),
thereby generating the light-source lighting-up signals

10 BL1 to BL4. Also, a notation (c) in FIG. 27 illus-
trates BL1 to BL4 in the case where many of the motion-
frame picture judgement signals exist in the regions Y1
and Y2 (i.e., the modes Y1, Y2). In order to optimize
the motion-frame picture displays in the regions Y1,

15 Y2, an optimum setting is performed with respect to
each of the regions, and the lighting-up control over
the light-source is executed under a condition that the
other regions Y3, Y4 are synchronized with the regions
Y1, Y2 (here, an average value between the optimum

20 setting of Y1 and that of Y2 is employed). Namely, in
the region Y1, ps 1 and pw 1 are set so that the 2nd
time-period will start immediately after the writing of
the display data in the region Y1 has been terminated
(i.e., the starting time of a n/4th signal scanning

25 when there exist the n signal scanning lines of the
display apparatus), thereby generating the light-source
lighting-up signal BL1. In the region Y2, ps 2 and pw
2 are set so that the 2nd time-period will start

immediately after the writing of the display data in the region Y2 has been terminated (i.e., the starting time of a 2n/4th signal scanning when there exist the n signal scanning lines of the display apparatus),

5 thereby generating BL2. In the regions Y3 and Y4, ps 3, ps 4 and pw 3, pw 4 are set so that the 2nd time-period will start immediately after the writing of an immediate row display data in the region Y2 has been terminated (i.e., the starting time of a 5n/8th signal

10 scanning when there exist the n signal scanning lines of the display apparatus), thereby generating BL3, BL4. Furthermore, a notation (d) in FIG. 27 illustrates BL1 to BL4 in the case where many of the motion-frame picture judgement signals exist in the regions Y1 and

15 Y3 (i.e., the modes Y1, Y3). In order to optimize the motion-frame picture displays in the regions Y1, Y3, an optimum setting is performed with respect to each of the regions, and the lighting-up control over the light-source is executed under a condition that the

20 other region Y2 is synchronized with the region Y1 and the other region Y4 is synchronized with the region Y3. Namely, in the regions Y1 and Y2, ps 1, ps 2 and pw 1, pw 2 are set so that the 2nd time-period will start immediately after the writing of the display data in

25 the region Y1 has been terminated (i.e., the starting time of a n/4th signal scanning when there exist the n signal scanning lines of the display apparatus), thereby generating the light-source lighting-up signals

BL1, BL2. In the regions Y3 and Y4, ps 3, ps 4 and pw 3, pw 4 are set so that the 2nd time-period will start immediately after the writing of an immediate line display data in the region Y3 has been terminated

5 (i.e., the starting time of a 3n/4th signal scanning when there exist the n signal scanning lines of the display apparatus), thereby generating BL3, BL4.

Additionally, FIG. 27 has illustrated the light-source lighting-up signals in correspondence with

10 the mode judging result of the motion-frame picture display. Being not limited thereto, however, it presents no problem at all to perform the setting so that the motion-frame picture display becomes the most appropriate. Also, although the explanation has been

15 given here regarding the method of performing the control in accordance with the mode judgement alone, as having been described earlier in FIG. 19, it presents no problem at all to set the starting times (i.e., ps 1 to ps 4) of the 1st time-period and the times (i.e., pw

20 1 to pw 4) of the 1st time-period in each region in correspondence with the total number of the motion-frame pictures.

Next, the description will be given below concerning a light-source lighting-up control in

25 response to the display luminance of a displayed image.

In the conventional light-source unit, since the fluorescent lamps are always lit up regardless of whether the image-signal is of the bright display or

the dark display, the energy efficiency has been
worsened. In contrast to this, the illumination light-
quantity of the light-source is controlled in compli-
ance with the information amount of the image-signal

5 (e.g., the luminance information or the like). This
enhances the light-emission efficiency of the fluores-
cent lamps, thereby making it possible to implement a
further luminance enhancement based on the saving of
the power consumption and the suppression of the rise

10 in the lamp temperature. Namely, the illumination
light-quantity of the light-source is decreased when
the image is dark, and the illumination light-quantity
is increased when the image is bright. In this way,
the time ratio of the above-described 1st time-period

15 (i.e., the lighting-up time-period) and that of the
above-described 2nd time-period (i.e., the pausing
time-period when the 2nd current is set to be 0 mA) are
changed in correspondence with the information on the
bright-or-dark of the image-signal, thereby making it

20 possible to control the light-source illumination
light-quantity. FIG. 28 is a diagram for illustrating
a switching controlling circuit 25 for performing this
lighting-up control. In the drawing, the reference
numerals denote the following components: 56 a display

25 luminance detecting unit for accumulating the luminance
information by the amount of 1 frame from the inputted
display data so as detect a display luminance (i.e.,
average luminance) level over the entire display

region, 57 a frame latch unit for latching the result

by the display luminance detecting unit 56 for a

constant time-period, 53 a pulse controlling unit

that, in accordance with the display luminance

5 detection result which is the output from 57, sets a

starting time ps of the 1st time-period and a time pw

of the 1st time-period in a light-source lighting-up

signal for each display region, and 54 a pulse

generating unit for generating the light-source

10 lighting-up signal BL by a line count value outputted

by a line count unit 51 and ps and pw outputted by the

pulse controlling unit 53. FIG. 29 illustrates a

timing diagram of the light-source lighting-up signal

BL generated by the switching controlling circuit 25

15 configured as described above.

A notation (a) in FIG. 29 illustrates the

light-source lighting-up signal BL in the case where,

as a result of the display luminance detecting unit 56,

the average luminance of the screen is found to be high

20 (i.e., bright). A notation (b) in FIG. 29 illustrates

BL in the case where the average luminance is found to

be immediate. A notation (c) in FIG. 29 illustrates BL

in the case where the average luminance is found to be

low (i.e., dark). Incidentally, when a switching is

25 made at a high-speed between the display data with a

high display luminance and the display data with a low

display luminance, if, in synchronization with this

switching, the light-source illumination light-quantity

is also switched at a high-speed, this switching is visualized as a flicker of the display, thus becoming a problem. Accordingly, in the present controlling circuit, the display luminance information latching

5 unit 57 is provided, thereby relaxing the high-speed switching of the light-source illumination light-quantity.

Also, depending on an image displayed on the liquid crystal display apparatus, or depending on the

10 user's convenience, there are some cases where the ordinary continuous lighting-up is employed instead of the blinking lighting-up of the light-source according to the present invention. On account of this, it is desirable to equip the above-described switching

15 controlling circuit with a section for inputting a lighting-up menu selection signal from the outside. FIG. 30 illustrates an example of this section. FIG. 30 is a diagram for illustrating the configuration of a lighting-up method instructing circuit 60, wherein the

20 reference numerals denote the following components: 61 an inputting-method judging unit for judging the input-ting method of a display image-signal, 62 a lighting-up selecting unit by which the user determines whether or not to employ the above-described blinking lighting-

25 up of the light-source (i.e., menu selection), and 63 a lighting-up instruction signal generating unit for outputting a lighting-up instruction signal for allowing the blinking lighting-up to be executed in

accordance with the output results from 61 and 62. At present, as the display apparatuses mounting the liquid crystal display apparatus thereon, there exist a liquid crystal monitor, a liquid crystal television, or the

5 like. As the inputting methods of the display image-signal of these apparatuses, there exist an analogue RGB inputting in use for a personal computer, a composite inputting and an S image terminal inputting in use for a video monitor, a color-difference input-

10 ting in use for a DVD player, an antenna inputting in use for a television, or the like. On account of this, the inputting-method judging unit 61 judges what the inputting method is in view of a connection state between the inputting methods and the display appara-

15 tuses. As the result by the inputting-method judging unit 61, if the inputting method is judged to be, e.g., the analogue RGB inputting in use for a personal computer, the lighting-up instruction signal generating unit 63 judges that there exist a few motion-frame

20 pictures, instructing the apparatus not to execute the blinking lighting-up of the light-source. Meanwhile, if the inputting method is judged to be, e.g., the inputting in use for a video monitor or a television, the unit 63 judges that most of the pictures are the

25 motion-frame pictures, instructing the apparatus to execute the blinking lighting-up of the light-source. Additionally, assuming that these will be set automatically, the menu selection plays a role of

allowing the user to freely select the blinking

lighting-up of the light-source.

<Embodiment 4>

In this embodiment, the explanation will be

5 given below concerning a system that, in correspondence

with the tone characteristic detection of input image

data, executes a tone control and a light-source

blinking lighting-up control which are suitable for the

motion-frame picture display. Incidentally, the

10 present embodiment describes, as its one configuration

example, a display system that the present inventor has

prototyped in order to confirm the effect actually with

the use of a TFT module mounting an 8-lamp directly-

under type backlight.

15 FIG. 31 is a schematic configuration diagram

of the liquid crystal display module according to the

present invention.

In FIG. 31, the reference numerals denote the

following components, respectively: 3101 a liquid

20 crystal module, 3102 a liquid crystal driving control

board (hereinafter, referred to as "TCON board"), 3103

an inverter board, 3104 a for-gate flat cable (herein-

after, referred to as "gate FPC"), 3105 a for-drain

flat cable (hereinafter, referred to as "drain FPC"),

25 3106 an inverter controlling cable (hereinafter,

referred to as "inverter cable"), 3107 a lamp high-

voltage side cable, and 3108 a lamp low-voltage side

cable.

As illustrated in FIG. 31, the TCON board
3102 and the inverter board 3103 are implemented on the
back surface of the liquid crystal module 3101. At
first, from the system side, an image-signal and a

5   power-supply voltage are fed to the TCON board 3102.
The TCON board 3102 executes processings such as an
image processing and a timing processing, then output-
ting the image-signal and a timing signal to the liquid
crystal module 3101 through the gate FPC 3104 and the

10   drain FPC 3105. At the same time, the TCON board
controls the inverter board 3103 through the inverter
cable 3106, and lights up the lamps with a tube current
quantity fed by the lamp high-voltage side cable 3107.
A back-current to the inverter board is returned back

15   through the lamp low-voltage side cable 3108.
Additionally, the present example illustrates the
directly-under type liquid crystal module where the
lamps are located with an equal spacing therebetween on
the back surface of the liquid crystal module.

20   FIG. 32 is a schematic configuration diagram
of the TCON board implemented on the back surface of
the liquid crystal display module according to the
present invention.

        In FIG. 32, the reference numerals denote the
25   following components, respectively: 3201 a low-voltage
differential digital image-signal inputting connector
unit (hereinafter, referred to as "image-signal
inputting connector unit"), 3202 an image data

conversion (i.e., low-voltage differential → TTL) LSI
1, 3203 a FPGA logic data setting connector, 3204 a
FPGA logic data setting ROM, 3205 a liquid crystal
panel controlling FPGA or LSI, 3206 an operation mode

5 setting SW of the FPGA (or the LSI) 3205, 3207 a frame
memory, 3208 an oscillator, 3209 a tone voltage
controlling comparator, 3210 a for-gate signal connec-
tor, 3211 a for-drain signal connector, 3212 variable
resister for common voltage setting, 3213 an image

10 data conversion (i.e., TTL → low-voltage differential)
LSI 2, 3214 a low-voltage differential digital image-
signal outputting connector unit (hereinafter, referred
to as "image-signal outputting connector unit"), 3215
a D/A conversion converter, 3216 an inverter control

15 connector unit, and 3217 a power-supply circuit unit.

At first, a low-voltage differential digital
image-signal from the system is inputted into the
image-signal inputting connector unit 3201. The
inputted image-signal is converted into an image-signal

20 of the TTL format by the image data conversion (i.e.,
low-voltage differential → TTL) LSI 1 3202. The image-
signal after being converted is inputted into the FPGA
or LSI 3205. Here, at the time of the FPGA mounting,
logical information that has been set in advance into

25 the FPGA logic data setting ROM 3204 through the FPGA
logic data setting connector 3203 is read into the
above-described FPGA 3205 simultaneously with the
starting-up. At the time of the LSI mounting, since a

logic circuit has been built in the LSI 3205 in advance, the FPGA logic data setting connector 3203 and the FPGA logic data setting ROM 3204 become unnecessary (Hereinafter, in the present embodiment, the explana-

5   tion will be given employing the LSI as the example). The setting in the operation mode setting SW 3206 controls various types of functions that the above-described LSI 3205 has. The above-described LSI 3205 allows the frame memory 3207 to be connected with the

10   outside thereof. The use of the frame memory 3207 permits an input/output asynchronous image processing to be executed. In this case, in an output-side (i.e., liquid crystal display side) image processing, it is also possible to use a specific clock generated by the

15   oscillator 3208. In the image data outputting form from the above-described LSI 3205, there exist 2 channels. The 1st channel is a channel where the image data is outputted to the liquid crystal panel 3101 so as to drive a built-in driver IC directly. In this

20   case, the image output from the LSI 3205 is outputted to the liquid crystal panel 3101 through the for-drain signal connector 3211. At the same time, the LSI 3205 outputs a gate signal to the liquid crystal panel 3101 through the for-gate signal connector 3210. At this

25   time, the V-B characteristic, which is a relationship between the tone data and the display luminance that correspond to the image output outputted through the for-drain signal connector 3211, is determined by the

tone voltage controlling comparator 3209 and a resist-
ance vale associated therewith. Also, a common voltage
adjusting VR 3212 adjusts the common voltage that
becomes a reference voltage for alternately-driving the
5 liquid crystal. The 2nd channel is a channel where the
image data outputted from the LSI 3205 is converted by
the image data conversion (i.e., TTL → low-voltage
differential) LSI 2 3213, then being outputted through
the image-signal outputting connector unit 3214. In
10 the above-described 2 image data outputting forms, the
display may be performed using the 1st channel alone.
Also, the LSI 3205 controls the D/A converter 3215 so
as to supply an output from the D/A converter 3215 to
the inverter board 3103 through the inverter control
15 connector unit 3216, thereby executing a brightness
control over the lamps. The power-supply circuit 3217
executes the generation of a power-supply voltage
needed inside the TCON board 3102, one example of which
is as follows: With +5V voltage employed as the input,
20 a DC/DC converter generates the power-supply voltages
of −4V, +2.5V, +3.3V, +5V, +15V, and +20V, respec-
tively.

FIG. 33 is a schematic configuration diagram
of the internal function of the LSIs mounted on the
25 TCON board according to the present invention.

In FIG. 33, the reference numerals denote the
following components, respectively: 3301 the low-
voltage differential digital image-signal, 3302 the

digital image-signal converted into the TTL format by
the image data conversion (i.e., low-voltage differen-
tial → TTL) LSI 1 3202, 3303 a timing control unit for
subjecting the digital image-signal to a reference

5 timing conversion inside the LSI 3205, 3304 R, G, and
B image data outputted by the timing control unit 3303,
3305 a reference timing signal inside the LSI outputted
similarly by the timing control unit 3303, 3306 a
luminance data generation controlling unit for generat-

10 ing luminance data from the R, G, and B image data,
3307 the luminance data outputted by the luminance data
generation controlling unit 3306, 3308 a luminance
distribution detection controlling unit for inputting
the luminance data 3307 so as to detect the luminance

15 distribution state within 1 screen, 3309 the luminance
distribution data outputted by the luminance distribu-
tion detection controlling unit 3308, 3310 a folded-
line point tone controlling unit for inputting the R,
G, and B image data 3304 and the luminance distribution

20 data 3309 so as to execute an output tone character-
istic control, 3311 the output tone data outputted by
the folded-line point tone controlling unit 3310, 3312
a frame memory controlling unit for controlling the
frame memory 3207, 3313 a frame memory interface

25 signal controlled by the frame memory controlling unit
3312, 3314 frame memory read data read out from the
frame memory 3207, 3315 an overdrive controlling unit
for controlling a corrected value of the output tone

data 3311 in accordance with the comparison result with
the frame memory read data 3314, 3316 after-correction
output tone data outputted by the overdrive controlling
unit 3315, 3317 a FRC controlling unit for increasing

5 the tone number in a pseudo manner from the after-
correction output tone data 3316, 3318 pseudo tone
display data outputted by the FRC controlling unit
3317, 3319 a driver interface controlling unit for
driving the driver IC inside the liquid crystal panel

10 3101, 3320 a gate driver controlling signal outputted
by the driver interface controlling unit 3319, 3321 a
drain driver controlling signal outputted similarly by
the driver interface controlling unit 3319, 3322 the
low-voltage differential digital image-signal outputted

15 by the image data conversion (i.e., TTL → low-voltage
differential) LSI 2 3213, 3323 a backlight light-
dimmer controlling unit for controlling the brightness
of the backlight with the luminance distribution data
3309 employed as the reference, 3324 a blink control-

20 ling unit for controlling the lighting-up time-period
and the non-lighting-up time-period of the backlight
with the luminance distribution data 3309 and the
reference timing signal 3305 inside the LSI employed as
the reference, 3325 a digital backlight light-dimmer

25 signal outputted by the backlight light-dimmer
controlling unit 3323, 3326 a backlight ON/OFF signal
outputted by the blink controlling unit 3324, 3327 an
analogue backlight light-dimmer signal outputted by the

D/A converter 3215, and 3328 an inverter controlling

signal outputted to the inverter board through the

inverter control connector unit 3216.

At first, the digital image-signal 3302

5 obtained by converting the low-voltage differential

digital image-signal 3301 into the TTL format is

inputted into the timing control unit 3303. Then, the

timing control unit outputs the delay-adjusted R, G,

and B image data 3304 and the reference timing signal

10 3305 becoming the reference inside the LSI 3205. The

outputted R, G, and B image data 3304 are inputted into

the luminance data generation controlling unit 3306 and

the folded-line point tone controlling unit 3310. The

luminance data generation controlling unit 3306

15 generates and outputs the luminance data 3307 from the

inputted R, G, and B image data 3304. This luminance

data is inputted into the luminance distribution

detection controlling unit 3308 at the next stage, and

the controlling unit outputs the luminance distribution

20 data 3309 where the luminance data by the amount of 1

frame has been accumulated. The luminance distribution

data 3309 is outputted to the folded-line point tone

controlling unit 3310 and the backlight light-dimmer

controlling unit 3323. The backlight light-dimmer

25 controlling unit 3323 judges a characteristic of the

image data for each frame from this luminance distribu-

tion information, thereby outputting the digital

backlight light-dimmer signal 3325 for obtaining an

excellent display. This light-dimmer signal 3325 is
inputted into the D/A converter 3215 so as to be
converted into the analogue backlight light-dimmer
signal 3327, then being outputted to the inverter

5   control connector unit 3216. Meanwhile, concerning the
ON/OFF control over the backlight, the blink control-
ling unit 3324 fetches the reference timing signal 3305
so as to control the lighting-up time-period and the
non-lighting-up time-period during the 1-frame time-

10   period, then, as the backlight ON/OFF signal 3326,
outputting the reference timing signal to the inverter
control connector unit 3216. The inverter control
connector unit 3216 independently outputs the analogue
backlight light-dimmer signal 3327 and the backlight

15   ON/OFF signal 3326 to the inverter control board 3103.
In the mean time, the image data processing is as
follows: The R, G, and B image data 3304 and the
luminance distribution data 3309 are inputted into the
folded-line point tone controlling unit 3310. The

20   folded-line point tone controlling unit 3310, as is the
case with the backlight control, judges the character-
istic of the image data for each frame from the
luminance distribution data 3309, thereby executing for
each frame the tone characteristic (i.e., the V-B

25   characteristic) setting for obtaining the excellent
display. The tone-controlled output tone data 3311 is
inputted into the overdrive controlling unit 3315, and
at the same time is written into the frame memory 3207

as the frame memory interface signal 3313 through the

frame memory controlling unit 3312. The tone data

stored into the frame memory 3207 is similarly read out

by the frame memory controlling unit 3312, then being

5   inputted into the overdrive controlling unit 3315 as

the frame memory read data 3314. Here, the output tone

data 3311 turns out to become tone data 1 frame after

with respect to the frame memory read data 3314. The

overdrive controlling unit 3315 detects a difference in

10   the tone data between these adjacent frames, then

judging the movement amount of the image data from this

difference. From this movement amount, the overdrive

controlling unit determines, for each frame, the

response-rate or the image data corrected-value at the

15   optimum for the luminance, thereby executing a

correction toward the output tone data 3311. The

after-correction output tone data 3316 outputted

thereafter is inputted into the FRC controlling unit

3317. The FRC controlling unit generates the pseudo

20   tone display data 3318 for performing a multi-tone

display in a pseudo manner in a liquid crystal panel

with a smaller tone number. The pseudo tone display

data 3318 is inputted into the driver interface

controlling unit 3319 together with the reference

25   timing signal 3305. Then, after being converted into

the gate driver controlling signal 3320 and the drain

driver controlling signal 3321, the display data is

outputted to the liquid crystal panel 3101 through the

for-gate signal connector 3210 and the for-drain signal
connector 3211. Also, as the 2nd channel, the pseudo
tone display data 3318 is directly outputted by the LSI
3205, then being outputted as the low-voltage differen-
5   tial digital image-signal 3322 through the image data
conversion (i.e., TTL → low-voltage differential) LSI 2
3213. Here, when implementing a liquid crystal module
that allows the display in the configuration illus-
trated in FIG. 31, the above-described 2nd channel is
10 unnecessary.

Table 1

SW NO.		function	setting condition
SW 1	1	light-dimmer control ON/OFF setting	1 = ON, 0 = OFF
	2	overdrive ON/OFF setting	1 = ON, 0 = OFF
	3	FRC ON/OFF setting	1 = ON, 0 = OFF
	4	blink ON/OFF setting	0 = ON, 1 = OFF
SW 2	1	blink duty setting	0 = 50 %, 1 = 60 %
	2	blink phase [0] setting	blink phase [2:0] = 0°∼360° delay setting equal assignment (1 step = 45° delay)
	3	blink phase [1] setting	
	4	blink phase [2] setting	
SW 3	1	overdrive characteristic setting [0]	4 μm product Super TFT panel
	2	overdrive characteristic setting [1]	
	3	overdrive characteristic setting [2]	characteristic setting [3:0] = [0, 1, 1,0]
	4	overdrive characteristic setting [3]	

Table 1 illustrates an example of the list of
various types of function settings that are mounted on

the LSI 3205 illustrated in FIG. 33 and are established by the operation mode setting SW 3206. The present example indicates the following settings: Valid/ invalid settings of the respective functions of the

5 backlight light-dimmer controlling unit 3323, the overdrive controlling unit 3315, the FRC controlling unit 3317, and the blink controlling unit 3324, the ratio setting of the in-1-frame lighting-up time-period at the time when the blink controlling unit 3324 is

10 valid, the phase setting of the same in-1-frame lighting-up time-period, and the optimum overdrive characteristic setting of the overdrive controlling unit 3315 in agreement with each liquid crystal panel. In this way, the various types of functions mounted on

15 the LSI 3205 have been made settable independently of each other.

Table 2

TTL image-signal		LVDS image-signal	
signal name	function	signal name	function
R[7:0]	red 8-bit image-signal	Y0+/Y0-	low-voltage differential channel 0
G[7:0]	green 8-bit image-signal	Y1+/Y1-	low-voltage differential channel 1
B[7:0]	blue 8-bit image-signal	Y2+/Y2-	low-voltage differential channel 2
DTMG	image valid signal	Y3+/Y3-	low-voltage differential channel 3
VSYNC	vertical synchronization signal	CLK+/CLK-	low-voltage differential channel CLK
HSYNC	horizontal synchronization signal		

Table 2 illustrates an input/output signal
specification of the image data conversion (i.e., low-
voltage differential → TTL) LSI 1 3202 and that of the
image data conversion (i.e., TTL → low-voltage

5 differential) LSI 2 3213. In the image data conversion
(i.e., low-voltage differential → TTL) LSI 1 3202, the
input becomes the LVDS image-signals and the output
becomes the TTL image-signals. In the image data
conversion (i.e., TTL → low-voltage differential) LSI 2

10 3213, the input/output become opposite thereto. The
TTL image-signals include the respective R, G, and B 8-
bit image-signals, the valid display time-period
signal, the vertical synchronization signal, and the
horizontal synchronization signal. The LVDS image-

15 signals include the 5 pairs of low-voltage differential
signals.

FIG. 34 illustrates a timing diagram for the
signal specifications illustrated in the above-
illustrated Table 2.

20 In FIG. 34, a single clock constitutes the 1
pair of low-voltage differential signal (CLK$_+$/CLK$_-$), and
its operation frequency is equal to an input clock
(CLKIN) frequency. The other 4 pairs of low-voltage
differential signals (Y0$_+$/Y0$_-$ ~ Y3$_+$/Y3$_-$) drive the

25 above-described input clock (CLKIN) frequency by 7-
multiplication. The TTL image-signals transfer the
respective R, G, and B 8-bit image-signals, the display
valid-time-period signal, the vertical synchronization

signal, and the horizontal synchronization signal.
Incidentally, TI-fabricated "SN75LVDS84", Thine-
fabricated "THC63LVDF84", or the like are available as
the image data conversion (i.e., low-voltage differen-
5 tial → TTL) LSI 1 3202. TI-fabricated "SN75LVDS83",
Thine-fabricated "THC63LVDF83", and the like are also
available as the image data conversion (i.e., TTL →
low-voltage differential) LSI 2 3213.

FIG. 35 illustrates a schematic timing
10 diagram of the operation of the frame memory control-
ling unit 3312 for controlling the frame memory 3207.
As the frame memory, when the resolution of the liquid
crystal panel is set to be of the XGA size, it is
possible to use a 16-Mbit product SD_RAM. The configu-
15 ration of the 16-Mbit product SD_RAM is 512 K×16 bits×
2 banks. Accordingly, since the data bus width is 16
bits wide, when employing the 24-bit configuration of
the respective R, G, and B 8-bit image-signals, the 2
memories are used each for the writing and the reading,
20 i.e., the 4 memories are used in total. When employing
a 16-bit configuration of 5-bit R, 6-bit G, and 5-bit B
image-signals, the 1 memory is used each for the
writing and the reading, i.e., the 2 memories are used
in total. The 1 horizontal time-period of the image
25 data is divided into a start-portion, an internal-
portion, and an end-portion, thereby executing the
command control. A full-page burst mode is employed
for the access and, after setting the commands, the

writing/reading control for each pixel is executed
continuously in synchronization the clock. The
horizontal start-portion generates the commands in the
sequence of MRS for executing the mode setting, ACTV

5   for executing a row address latch and a bank selection,
and READ/WRIT for setting the read or the write. The
horizontal internal-portion generates the commands in
the sequence of the ACTV for executing the row address
latch and the bank selection, the READ/WRIT for setting

10   the read or the write, and PRE for executing a pre-
charge processing of a bank selected by the address.
The horizontal end-portion generates the commands in
the sequence of WBST/RBST for stopping the full-page
burst processing of the read or the write, PALL for

15   executing the pre-charge processing of all the banks,
and REF for executing a refresh operation automati-
cally. The processing in the 1 horizontal time-period
is executed by the generation of the above-mentioned
commands. Concerning the vertical direction, the same

20   processing is repeated in a time-period during which
the display valid-time-period signal is valid, thereby
executing the image data processing by the amount of 1
frame.

Table 3

signal name	main function
CL 1	data (1-line amount) latch & output signal
CL 2	data fetch clock
STH	data fetch start signal
M	alternating current converting signal
FLM	shift data fetch signal
CL 3	data shift clock

Table 3 illustrates the function list of the gate driver controlling signal 3320 and the drain driver controlling signal 3321. The gate driver controlling signal 3320 includes the shift data fetch signal (FLM) and the data shift clock (CL 3). The drain driver controlling signal 3321 includes the data (1-line amount) latch & output signal (CL 1), the data fetch clock (CL 2), the data fetch start signal (STH), and the alternating current converting signal (M), respectively.

Table 4

item	symbol	set value	unit	remark
data delay	tDATA	5	TPIC	
STH delay	tSTH	5	TPIC	
drain output timing	tCL1	1040	TPIC	
CL 1 pulse-width	tCL1W	80	TPIC	
M set up	tM	8	TPIC	
FLM delay	tF	4	TPIC	
gate delay	tGD	949,857,767, 663	TPIC	1.4us,2.8us, 4.2us,5.8us

Table 4 and FIG. 36 illustrate an example of the driver interface timing setting specification illustrated in Table 3. The respective interface signals are generated from the dotclock (CK) that is

5 the reference signal inside the LSI 3205, a horizontal start pulse (HCLK), and a horizontal display valid-time-period signal (HDTMG).

Table 5

signal name	main function
DACLK	D/A converter control clock
DACSN	D/A converter control chip selection signal
DADATA	D/A converter input digital data

Table 5 illustrates the function list of the digital backlight light-dimmer signal 3325. The

10 digital backlight light-dimmer signal 3325 has the D/A converter control clock (DACLK), the D/A converter control chip selection signal (DACSN), and the D/A converter input digital data (DADATA). As the D/A converter that matches this function, e.g., "AD5300"

15 (fabricated by Analogue Device) or the like is applicable.

Table 6

signal name	main function	set value
D[15]-D[14]	Don't care	all "0"
D[13]-D[12]	Mode set	all "0"
D[11]-D[04]	Set data	per-frame updating
D[03]-D[00]	Don't care	all "0"

Table 6 and FIG. 37 illustrate an example of
the digital backlight light-dimmer signal timing
specification fitted to the AD5300 (fabricated by
Analogue Device). The D/A converter input digital data

5   (DADATA) is transferred in series. The header's 2 bits
(i.e., D[15]-D[14]) mean being undefined, and the
subsequent 2 bits (i.e., D[13]-D[12]) mean a mode
setting, and the further subsequent 8 bits (i.e.,
D[11]-D[04]) mean the data, and the remaining 4 bits

10 (i.e., D[03]-D[00]) mean being undefined. Here, the 2-
bit (i.e., D[13]-D[12]) mode setting is "all 0" which
is the setting of a normal operation, and the 8-bit
(i.e., D[11]-D[04]) data is the digital backlight
light-dimmer signal 3325 outputted from the backlight

15 light-dimmer controlling unit 3323 in accordance with
the luminance distribution data 3309 in FIG. 33.

As having been explained so far, as illus-
trated in FIGS. 31 to 37 and in Tables 1 to 6, the
controlling circuit of the liquid crystal display

20 apparatus according to the present invention includes
the following components that implement its main

functions: The LSI, the frame memory, the low-voltage differential transferring LSIs, and the D/A converter.

Hereinafter, the detailed explanation will be given concerning the tone control function and the

5   backlight control function in compliance with the input image data, which are mounted on the above-described LSI 3205 and are the primary object of the present invention.

FIG. 38 illustrates a conceptual diagram of

10   the operation of the above-described luminance data generation controlling unit 3306.

In FIG. 38, in the case where the luminance data (Y) is generated from the R, G, and B image data, the ratios of the respective colors are given by the

15   following formula (i.e., formula 1):

(formula 1)

luminance data (Y) = 0. 299 × R (red) + 0. 587
× G (green) + 0. 144 × B(blue)

Processing this formula precisely with the

20   hardware is difficult because of an increase in the circuit size, a decrease in the processing speed, and so on. Also, the luminance data generated here is the data for obtaining the characteristics of the display data. Taking this into consideration, the approxima-

25   tion processing is executed so that the luminance data can be implemented with the hardware. Since the processing in a pixel unit is required, it has been planned to implement the luminance data by the shift

and the addition processing. In FIG. 38, assuming that the R, G, and B image data are 8-bit digital image data respectively, the R color is shifted by 2 bits and by 5 bits in the right direction (a 1-bit shifting in the right direction means a division by 2, and a n-bit shifting means a division by the nth power of 2), and the G color is shifted by 1 bit and by 4 bits in the right direction, and the B color is shifted by 3 bits, then adding all the respective shift data. This procedure allows the following approximation processing formula for the above-presented formula (i.e., formula 1):

(formula 2)

luminance data (Y) = 0. 281 × R (red) + 0. 563 × G (green) + 0. 125 × B(blue)

FIG. 39 illustrates a schematic configuration diagram of the luminance distribution detection controlling unit 3308.

In FIG. 39, the reference numerals denote the following configuration components, respectively: 3901 a detection time-period setting unit for setting a detection time-period at 1-time, 3902 an input tone division-number setting unit for setting a division-number of an input entire tone region, 3903 an input image data tone region detecting unit for detecting to which region the input image data corresponds among the respective divided tone regions set in the input tone division-number setting unit 3902, 3904 a 1st tone

region counter for counting data in a lowest tone

region, 3905 a 2nd tone region counter for counting

data in a 2nd-lowest tone region, 3906 a nth tone

region counter for counting data in a highest tone

5   region, 3907 a 1st data hold latch for latching the

total number of the data in the lowest tone region in

the detection time-period at 1-time, 3908 a 2nd data

hold latch for latching the total number of the data in

the 2nd-lowest tone region similarly, 3909 a nth data

10 hold latch for latching the total number of the data in

the highest tone region similarly, 3910 a m-times

multiplication circuit for multiplying, by m, a counted

value by the 1st tone region counter 3904, 3911 a 2*m-

times multiplication circuit for multiplying, by 2*m, a

15 counted value by the 2nd tone region counter 3905,

3912 a n*m-times multiplication circuit for multiply-

ing, by n*m, a counted value by the nth tone region

counter 3906, 3913 an addition circuit for adding

output data from the respective multiplication

20 circuits, 3914 a n*m division circuit for dividing, by

n*m, an output from the addition circuit 3913, and

3915 an average luminance data hold latch for latching

an output from the division circuit 3914 as an average

luminance value.

25   At first, the detection time-period at 1-time

is set into the detection time-period setting unit

3901. The output from this setting unit becomes a

latch clock for a final-stage data hold latch of the

respective detecting functions. Also, the division-number of the input entire tone region is set into the input tone division-number setting unit 3902. Here, as an example, it is assumed that the input entire tone

5   region is set to be 256 tones (8 bits) and the division-number is set to be 8 divisions. The output from this setting unit is inputted into the input image data tone region detecting unit 3903. This detecting unit judges to which region the tone value of the input

10   image data corresponds among the respective divided tone regions from the input tone division-number setting unit 3902, then outputting a region-counting clock corresponding to the region. Here, from the setting that the input entire tone region is of 256

15   tones and the division-number is 8, the tone range of each divided tone region becomes a 32-tone basis region. Accordingly, in order to enhance the characteristic detection accuracy of the input image data, it is advisable to increase the division-number

20   and the tone number of each divided tone region. The enhancement in the accuracy, however, results in an increase in the circuit size. Consequently, depending on the usage, the accuracy has been made changeable. Based on the clock from the input image data tone

25   region detecting unit 3903, the 1st tone region counter 3904, the 2nd tone region counter 3905, and the nth tone region counter 3906 count the data numbers for each divided tone region. During the setting time-

period by the detection time-period setting unit 3901,
the 1st data hold latch 3907, the 2nd data hold latch
3908, and nth data hold latch 3909 latch the data
numbers as the luminance distribution data, thereby

5 executing the detection of the luminance distribution.
The detection of the average luminance value is
executed as follows: The respective outputs from the
1st tone region counter 3904, the 2nd tone region
counter 3905, and the nth tone region counter 3906 are

10 multiplied by the m-times multiplication circuit 3910,
the 2*m-times multiplication circuit 3911, and the n*m-
times multiplication circuit 3912, respectively. Next,
the respective outputs from the multiplication circuits
are added by the addition circuit 3913, and the output

15 from the addition circuit is divided by the n*m divi-
sion circuit 3914. Finally, during the setting time-
period by the detection time-period setting unit 3901,
the output from the division circuit is latched as the
average luminance data by the average luminance data

20 hold latch 3915, thereby executing the detection of the
average luminance value. Here, m means the tone number
within each divided tone region, and becomes equal to
32 in the present example. Consequently, when employ-
ing a 16-bit configuration for the respective multipli-

25 cation circuits 3910 to 3912 and the addition circuit
3913, the division by the division circuit 3914 becomes
a one by n*m = 8*32 = 256. This division can be
implemented by a simple logic of the 8-bit shift

processing in the right direction (i.e., the higher-
order 8 bits are selected).

FIG. 40 is a state transition diagram for
illustrating the operation of a luminance distribution
5   detecting unit in the schematic configuration diagram
of the luminance distribution detection controlling
unit 3308 illustrated in FIG. 39. FIG. 40 illustrates
the following case used as the one example of the
explanation in FIG. 39: The input entire tone region
10 is set to be 256 tones (8 bits), and the division-
number is set to be 8 divisions, and the resolution of
the input image data is set to be the XGA size (i.e.,
1024 dots×768 lines).

In FIG. 40, the detection time-period setting
15 unit 3901 includes vertical synchronization signals
(inVsync) and display valid-time-period signals
(inDtmg). The valid display data are displayed at the
time when the display valid-time-period signals
(inDtmg) are valid. The luminance distribution
20 results, which are updated on the 1-frame basis, are
updated in timings of the vertical synchronization
signals (inVsync). As the counters (i.e., elemCntr)
for accumulating the luminance data number in the
respective divided tone regions, 8 of the counters
25 (i.e., elemCntr00 to elemCntr07) are prepared since the
divided tone regions are of 8 divisions. Then, the
corresponding counter's value is added to a result
obtained by decoding the higher-order 3 bits of the 8-

bit tone data. The accumulated 1-frame amount of

luminance distribution results are updated (i.e.,

hist00 to hist07) in the timings of the vertical

synchronization signals (inVsync). Here, it is

5   required that the size of the respective counters be

presented assuming that the same tone data exist by the

amount of 1 frame. The present example employs the XGA

resolution, which requires the counters equivalent to

the amount of 1024×768 = 786432 pixels. Namely, 20-bit

10   counters become necessary.

        FIG. 41 illustrates a schematic diagram for

showing the luminance distribution detection result

obtained by the luminance distribution detection

controlling unit in accordance with FIGS. 39 and 40,

15   and an arithmetic-calculation formula for calculating

the luminance average value from the detection result.

        As illustrated in FIG. 41, the luminance

distribution state makes it possible to extract the

per-frame light-and-shade state of the image data.

20   Also, the luminance average value makes it possible to

extract the per-frame screen brightness.

        As another example of the state transition

diagram illustrated in FIG. 40 where the input entire

tone region is set to be 256 tones (8 bits) and the

25   division-number is set to be 8 divisions, FIG. 42

illustrates a state transition diagram under the

following setting condition: The input entire tone

region is set to be 256 tones (8 bits), and the

division-number is set to be 20 divisions, and 8-divided tone regions on the lower-order side and those on the higher-order side are set to be of a 8-tone basis division, and 4-divided immediate tone regions

5   are set to be of a 32-tone basis division.

In FIG. 42, concerning the counters (i.e., elemCntr) for accumulating the luminance data number in the respective divided tone regions, the divided tone regions are of 20 divisions. On account of this, 20 of

10   the counters (i.e., elemCntr00 to elemCntr19) are prepared. Here, in the respective 8-divided tone regions on the lower-order side and on the higher-order side, the corresponding counter's value is added to a result obtained by decoding the higher-order 5 bits of

15   the 8-bit tone data (i.e., elemCntr00 to elemCntr07, elemCntr12 to elemCntr19). In the 4-divided immediate tone regions, the corresponding counter's value is added to a result obtained by decoding the higher-order 3 bits of the 8-bit tone data (i.e., elemCntr08 to

20   elemCntr11). The other controls are executed in much the same way as the case of the 8-divided tone regions illustrated in FIG. 40. Namely, the accumulated 1-frame amount of luminance distribution results are updated (i.e., hist00 to hist19) in the timings of the

25   vertical synchronization signals (inVsync). Also, similarly to the previously-described case, it is required that the size of the respective counters be presented assuming that the same tone data exist by the

amount of 1 frame. Namely, the present example employs the XGA resolution, which requires the counters equivalent to the amount of the $1024 \times 768 = 786432$ pixels. This indicates that the 20-bit counters become

5 necessary.

FIG. 43 illustrates a schematic diagram for showing the luminance distribution detection result in the case where the tone dividing control in accordance with FIG. 42 is executed, and an arithmetic-calculation

10 formula for calculating the luminance average value from the detection result.

As illustrated in FIG. 43, in comparison with the case of the 8-divided tone regions illustrated in FIG. 41, the luminance distribution state makes it

15 possible to detect the distribution states of the lower-order and the higher-order tone portions in more detail. Also, the luminance average value makes it possible to extract the per-frame screen brightness similarly to the case of the 8-divided tone regions

20 illustrated in FIG. 41.

FIG. 44 illustrates one example of the tone control performed by the above-described folded-line point tone controlling unit 3310 using the luminance distribution detection results illustrated in FIG. 40

25 and FIG. 42 at the time when the tone region is divided into the 8 regions.

In FIG. 44, in the tone control according to the folded-line point method, 9 folded-line points are

set on the 1-frame basis first. Next, between the

adjacent points, the input tone data inputted on a 1-

dotclock basis is converted into output tone data in

accordance with a straight-lined arithmetic-calculation

5   formula, thereby, in real time, implementing the output

tone data between the adjacent points. Here, in the

case of the equally-8-divided tone regions, an

arithmetic-calculation formula of the following formula

3 can be employed as the straight-lined arithmetic-

10   calculation formula between the adjacent points:

(formula 3)

output tone data = (rkinji (n) — rkinji (n—1))

$$\times M/32$$

rkinji (n): higher-order side folded-line point

15   set values

rkinji (n—1): lower-order side folded-line point

set values

M: lower-order 5 bits of input tone data

Here, the folded-line points are set as an

20   example where the luminance distribution data illus-

trated in FIG. 41 is caused to be reflected so as to

implement a higher picture-quality. The folded-line

points are set in such a manner as to correspond to the

luminance distribution accumulation number in each

25   divided tone region. In this case, if the detected

luminance distribution number in each tone region is

larger as compared with an average value m (which, in

the present example, is equal to a value obtained by

dividing the 1-frame amount of pixel number by 8, i.e.,
the number of the divided tone regions) of the
luminance distribution numbers within 1 frame, the
distribution number in the tone region is judged to be

5   larger than the average value. Based on this judge-
ment, the higher-order side folded-line points are made
larger as compared with the points (i.e., ○ points in
the drawing) at the time of a linear characteristic.
This procedure increases the dynamic range in the tone

10   region, thereby making it possible to obtain the
excellent picture-quality. Conversely, if the detected
luminance distribution number in each region is smaller
as compared with the average value m, the distribution
number in the tone region is judged to be smaller than

15   the average value, and the higher-order side folded-
line points are made smaller as compared with the
points (i.e., the ○ points in the drawing) at the time
of the linear characteristic. Although this procedure
decreases the dynamic range in the tone region, it can

20   increase the dynamic ranges in the tone regions the
luminance distribution numbers of which have exceeded
the average value. This condition, eventually,
enhances the contrasts of the regions occupying most of
the distributions as the screen as a whole, thereby

25   allowing the excellent picture-quality to be obtained.

FIG. 45 is a schematic configuration diagram
of the folded-line point tone controlling unit 3310
using the luminance distribution detection result

illustrated in FIG. 44 at the time when the tone region
is divided into the 8 regions.

In FIG. 45, the reference numerals denote the
following configuration components: 4501 a latch
5 circuit 1 for latching the input image data, 4502 a 1-
to-8 decoder circuit by the higher-order 3 bits out of
output image data from the latch circuit 1 4501, 4503
a higher-order tone side folded-line point setting
register/selector circuit, 4504 a lower-order tone
10 side folded-line point setting register/selector
circuit, 4505 a subtraction circuit for subtracting a
selected value by the lower-order tone side folded-line
point setting register/selector circuit 4504 from a
selected value by the higher-order tone side folded-
15 line point setting register/selector circuit 4503,
4506 a multiplication circuit for multiplying, by an
output result from the subtraction circuit 4505, a
value obtained by delaying the output from the latch
circuit 1 4501 with the use of latch circuits 2 to 5
20 4508 to 4511, and 4507 an addition circuit for adding,
to an output result from the multiplication circuit
4506, a value obtained by delaying the output from the
lower-order tone side folded-line point setting
register/selector circuit 4504 with the use of latch
25 circuits 6, 7 4512, 4513.

The controlling circuits illustrated in FIG.
45 play a role of implementing the straight-lined
formula between the respective folded-line points

illustrated in FIG. 44. In the controlling circuits, the higher-order tone side folded-line point setting register/selector circuit 4503 and the lower-order tone side folded-line point setting register/selector

5 circuit 4504 set the folded-line point set values corresponding to the luminance distribution state (i.e., rkinji00 to rkinji08) while updating the folded-line point set values on the 1-frame basis. Consequently, when the per-pixel image data (i.e., ridata

10 [7:0]) is inputted, the controlling units select 2 adjacent folded-line point set values so as to perform the arithmetic-calculation between the selected 2 tones, then outputting the image data (i.e., rodata [7:0]). There exists an 8-clock delay from the input-

15 ting of the input image data (i.e., ridata [7:0]) to the obtaining of the output image data (i.e., rodata [7:0]).

The present control permits an optimum tone control to be executed in harmony with the character-

20 istics of the per-frame image data.

FIG. 46 illustrates one example of the tone control performed by the folded-line point tone controlling unit 3310 using the luminance distribution detection result illustrated in FIG. 43 at the time

25 when the tone region is divided into the 20 regions.

In FIG. 46, in the tone control according to the folded-line point method, 20 folded-line points are set on the 1-frame basis first. Next, between the

adjacent points, the input tone data inputted on a 1-dotclock basis is converted into output tone data in accordance with a straight-lined arithmetic-calculation formula, thereby, in real time, implementing the output

5   tone data between the adjacent points. Here, the straight-lined arithmetic-calculation formula between the adjacent points differs between the case of the equally-8-tone-basis-divided lower-order and higher-order tone regions (i.e., hist00 to hist08, hist12 to

10   hist19) and the case of the 32-tone-basis-divided immediate tone regions (i.e., hist08 to hist11). In the cases, arithmetic-calculation formulae of the following formulae 4, 5 can be employed, respectively:
(formula 4)

15   output tone data = $(\text{rkinji}(n) - \text{rkinji}(n-1))$
$\times M/8$

rkinji (n): higher-order side folded-line point
set values

rkinji $(n-1)$: lower-order side folded-line point

20   set values

M: lower-order 3 bits of input tone data
(formula 5)

output tone data = $(\text{rkinji}(n) - \text{rkinji}(n-1))$
$\times M/32$

25   rkinji (n): higher-order side folded-line point
set values

rkinji $(n-1)$: lower-order side folded-line point
set values

M: lower-order 5 bits of input tone data

Accordingly, as an example where the luminance distribution data illustrated in FIG. 43 is caused to be reflected so as to implement a higher

5   picture-quality, performing a 2-step tone control allows the implementation. The 1st step tone control is as follows: With respect to the lower-order and the higher-order tone regions divided on the 8-tone basis, the usage frequencies on the 1-frame basis are

10 confirmed from the outer regions, respectively (i.e., hist00 in the lower-order tone region, hist19 in the higher-order tone region), thereby determining tone regions that can be crushed. Namely, the accumulation values are compared with a predetermined threshold

15 value of the tone accumulation numbers from the outside of the respective tone regions, then crushing the tones up to a region that has exceeded the threshold value. In the lower-order tone region in FIG. 46, since hist04 has exceeded the threshold value n, the distribution

20 frequencies of the tones prior thereto are judged to be smaller. Thus, 5 folded-line points from the lowest (i.e., rkinji00 to rkinji04) are set to be "0 tone". Similarly, in the higher-order tone region, since hist17 has exceeded the threshold value n, the

25 distribution frequencies of the tones prior thereto are judged to be smaller. Thus, 4 folded-line points from the highest (i.e., rkinji17 to rkinji20) are set to be "255 tones". Instead of crushing the portions existing

at both of the tone ends and having the smaller accumu-
lation numbers, this 1st step tone control makes it
possible to extend the dynamic ranges in the remaining
tone regions. Also, in the present example, as the

5   judging criterion for the tone regions to be crushed,
the comparison with the threshold value n has been
executed for each tone region independently. An
algorithm for crushing the tone regions, however, is
made available in a large variety of ways by the

10   combination with the software processing, such as the
comparison between the accumulation values from the
tone regions at both ends and the threshold value n.
In addition to the dynamic range's extension in the
entire tone region by the 1st step, the 2nd step tone

15   control is as follows: As having been explained in
FIG. 44, the comparison with the luminance distribution
average value m is performed for each distribution tone
region. If the comparison result is larger, the
higher-order side folded-line point set values are set

20   to be larger as compared with the values (i.e., O
points in the drawing) at the time of the linear
characteristic so that the dynamic range in the tone
region will be extended even further. Also, if the
comparison result is smaller, the higher-order side

25   folded-line point set values are set to be smaller as
compared with the values at the time of the linear
characteristic so that the dynamic range in the tone
region will be reduced. FIG. 46 illustrates the one

example where the 2-step tone control has been applied to the 32-tone-basis-divided immediate tone regions (i.e., rkinji09 to rkinji12). In FIG. 46, the extension control regions of the dynamic ranges by the 1st step are designated as histogram extension control regions, and the extension control region of the dynamic range by the 2nd step is designated as an equalize control region.

Also, the extension application range of the dynamic ranges by the 2-step is not limited to the 32-tone-basis-divided immediate tone regions (i.e., rkinji09 to rkinji12), and the 2-step may be applied to the 8-tone-basis-divided higher-order tone regions (i.e., rkinji04 to rkinji17 in FIG. 46).

As described above, the tone controlling method illustrated in FIG. 46 makes it possible to obtain an excellent display the dynamic range of which has been extended even further as well as to cover the tone controlling method illustrated in FIG. 44.

FIG. 47 is a schematic configuration diagram of the above-described folded-line point tone controlling unit 3310 using the luminance distribution detection result illustrated in FIG. 46 at the time when the tone region is divided into the 20 regions.

In FIG. 47, the reference numerals denote the following configuration components: 4701 a latch circuit 1 for latching the input image data, 4702 a 1-to-8 decoder circuit by the higher-order 3 bits out of

output image data from the latch circuit 1 4701, 4703
a higher-order tone side folded-line point setting
register/selector circuit for the respective lower-
order tone, immediate tone, and higher-order tone

5 divided tone regions, 4704 a lower-order tone side
folded-line point setting register/selector circuit for
the respective lower-order tone, immediate tone, and
higher-order tone divided tone regions, 4705 a 3-to-1
selector circuit for selecting one of outputs from the

10 higher-order tone side folded-line point setting
register/selector circuit 4703 for the respective
lower-order tone, immediate tone, and higher-order tone
3-divided tone regions, 4706 a 3-to-1 selector circuit
for selecting one of outputs from the lower-order tone

15 side folded-line point setting register/selector
circuit for the respective lower-order tone, immediate
tone, and higher-order tone 3-divided tone regions,
4707 a subtraction circuit for subtracting the selected
value by the lower-order tone side 3-to-1 selector

20 circuit 4706 from the selected value by the higher-
order tone side 3-to-1 selector circuit 4705, 4708 a
multiplication circuit separated into 2 channels of the
lower-order and higher-order tones and the immediate
tone for multiplying, by an output result from the

25 subtraction circuit 4707, a value obtained by delaying
the output from the latch circuit 1 4701 with the use
of latch circuits 2 to 6 4711 to 4714, 4709 a 2-to-1
selector circuit for selecting either of output results

from the 2-channel multiplication circuit 4708, and
4710 an addition circuit for adding, to the output from
the 2-to-1 selector circuit 4709, a value obtained by
delaying the output from the lower-order tone side 3-

5 to-1 selector circuit 4706 with the use of latch
circuits 7 to 9, 4716 to 4718.

As is the case with the controlling circuits
illustrated in FIG. 45, the controlling circuits
illustrated in FIG. 47 play a role of implementing the

10 straight-lined formula between the respective folded-
line points illustrated in FIG. 46. In the controlling
circuits, the higher-order tone side folded-line point
setting register/selector circuit 4703 and the lower-
order tone side folded-line point setting register/

15 selector circuit 4704 set the folded-line point set
values corresponding to the luminance distribution
state (i.e., rkinji00 to rkinji20) while updating the
folded-line point set values on the 1-frame basis.
Consequently, when the per-pixel image data (i.e.,

20 ridata [7:0]) is inputted, the controlling units select
2 adjacent folded-line point set values so as to
perform the arithmetic-calculation between the selected
2 tones, then outputting the image data (i.e., rodata
[7:0]). There exists a 10-clock delay from the input-

25 ting of the input image data (i.e., ridata [7:0]) to
the obtaining of the output image data (i.e., rodata
[7:0]). Accordingly, the present control also permits
the optimum tone control to be executed in harmony with

the characteristics of the per-frame image data.

Next, the explanation will be given below regarding the luminance control and an improving control over the motion-frame picture blur with the use

5 of the digital backlight light-dimmer signal 3325 and the backlight ON/OFF signal 3326 illustrated in FIG. 33.

FIG. 48 illustrates an example of the light-dimmer characteristic diagram in the above-described

10 inverter board 3103. The voltage as an input is made variable from 0 V to 3.3 V, and the duty ratio of an output pulse is changed in response to the voltage. Namely, the lower the input voltage becomes, the larger the pulse-width duty ratio becomes and conversely, the

15 higher the input voltage becomes, the smaller the pulse-width duty ratio becomes. Since the duty ratio corresponds to the ON/OFF of the backlight, the backlight becomes brighter as the voltage level becomes lower and conversely, the backlight becomes darker as

20 the voltage level becomes higher. Consequently, the digital backlight light-dimmer signal 3325 from the above-described backlight light-dimmer controlling unit 3323 is controlled in the scheme illustrated in Tables 5, 6 and in FIG. 37, then being fed into the above-

25 described D/A converter 3215. Based on the analogue backlight light-dimmer signal 3327 outputted from the D/A converter 3215 in this way, the light-dimmer control is executed with the inverter board's

characteristic illustrated in FIG. 48.

FIG. 49 illustrates an example of the luminance control and the improving control over the motion-frame picture blur by the backlight light-dimmer

5   controlling unit 3323 and the blink controlling unit 3324. In the present example, the explanation will be given regarding the case where the light-dimmer control and the blink control are executed using the control signals independent of each other.

10   FIG. 49 is a diagram for illustrating the case where, with respect to the continuous per-frame image data, the luminance distribution data outputted from the above-described luminance distribution detection controlling unit 3308 are transferred in the

15   order of a bright image → a bright image → a dark image.

In general, when displaying a motion-frame picture with a liquid crystal display apparatus, if the motion-frame picture is a bright image, the motion-

20   frame picture blur phenomenon that accompanies the response-rate exceeding 1 frame becomes less conspicuous and worrying as compared with the case of a dark image. Conversely, if, taking the motion-frame picture blur into consideration, the blink pulse-width for the

25   bright image is narrowed, the bright image is converted into a dark image, which, subjectively, will become conspicuous and worrying. Accordingly, the voltage level of the analogue backlight light-dimmer signal

3327 is lowered for the bright image, thereby increasing the pulse-width duty ratio of the light-dimmer waveform for the backlight. Conversely, the voltage level of the analogue backlight light-dimmer signal

5   3327 is heightened for the dark image, thereby decreasing the pulse-width duty ratio of the light-dimmer waveform for the backlight. Also, the present control causes the luminance distribution data to be reflected onto the next frame detected. This is

10 expressed by the relationship between the luminance distribution detection data and the light-dimmer waveform. Moreover, the blink control is executed in order to improve the motion-frame picture blur phenomenon resulting from the fact that the response-

15 rate necessitates a time of the 1-frame time-period or more. In FIG. 49, the target is set onto a lower screen portion of the display screen, and the control is performed so that the blink waveform is switched ON in the latter-half of the 1-frame time-period. Namely,

20 in FIG. 49, assuming that the time needed for the 1-frame time-period is equal to "a" and the time during which the blink waveform is kept ON in the latter-half of the 1-frame time-period is equal to "b", the blink waveform duty ratio becomes equal to a ratio of "b :

25 a", which will be fixed in the present example. The blink controlling unit 3324 in FIG. 33 executes the present control, using the vertical reference timing signal 3305 from the timing control unit 3303. The

actual backlight ON/OFF waveform turns out to become a waveform resulting from superimposing the blink waveform for the motion-frame picture blur improving control on the light-dimmer waveform for the light-

5 dimmer control. The liquid crystal luminance waveform based on this waveform turns out to become the sloped-line portions in FIG. 49. This lengthens the light-emission time of the luminance waveform if the luminance distribution detection data is judged to be

10 of the bright image (conversely, this shortens the light-emission time of the luminance waveform if the luminance distribution detection data is judged to be of the dark image). Also, it turns out that the light-emissions occur in the stationary timings of the liquid

15 crystal response waveform (no light-emissions occur in the transient timings). This condition makes it possible to obtain an excellent display state without the motion-frame picture blur.

        FIG. 50 illustrates an example of the image

20 judgement based on the luminance distribution detection data in the example illustrated in FIG. 49. FIG. 50 illustrates the luminance distribution detection data in the case where, as illustrated in FIG. 41, the entire tone region is equally divided into the 8

25 regions and the resolution of the input image data is set to be the XGA size (i.e., 1024×768). In this case, the number of the pixels by the amount of 1 frame is given by the following formula (i.e., formula 6):

(formula 6)

1-frame total pixel number = 1024 dots × 768 lines

= 786432 = C0000h

Here, in order to suppress the circuit size,
5 the judgement is performed employing only the higher-
order bits of the detected data. In the case of FIG.
50, the higher-order 8 bits are employed. The higher-
order 8 bits become "C0h" in the hexadecimal number
system, and become "192" in the decimal number system.
10 Consequently, the average point number in the respec-
tive equally-8-divided tone regions becomes equal to 24
points. In the present example, as illustrated in FIG.
50, if, as the image judging condition, the point
numbers in the respective tone regions e, f, g, and h
15 (i.e., 128 to 159, 160 to 191, 192 to 223, and 224 to
255 tones) are each larger than any one of 48, 40, 32,
and 24 points, the case is judged to be of the bright
image, and all the cases other than the above-described
condition are judged to be of the dark image.

20 FIG. 51 illustrates an example of a state
transition diagram of the light-dimmer control in
accordance with the image judging condition's example
illustrated in FIG. 50.

In the present example illustrated in FIG.
25 51, the light-dimmer control is performed in a light-
dimmer range ranging from a maximum luminance to a
minimum luminance that is set to be 85 % of the maximum
luminance. Between both of the luminances, the

transition is performed for each frame in accordance with the image judging condition illustrated in FIG. 50. The transition time from the maximum luminance to the minimum luminance or from the minimum luminance to

5 the maximum luminance is set to necessitate 40 frames (i.e., about 0.67 seconds in the case where the 1 frame is of 60 Hz) at the minimum. This is intended to prevent the occurrence of a flicker. Here, the flicker occurs by the control such that, when the bright images

10 and the dark images are inputted alternately for each frame, the transition is performed between the maximum and the minimum luminances in the 1 frame. Consequently, at a point-in-time when the image judging condition is inverted halfway during the transition,

15 the transition moves in the opposite direction at the point-in-time.

As having been described so far, the light-dimmer waveform control illustrated in FIG. 49 is executed in accordance with the light-dimmer control-

20 ling algorithms illustrated in FIGS. 50 and 51.

FIG. 52 illustrates another example that differs from the example illustrated in FIG. 49 of the luminance control and the motion-frame picture blur improving control by the backlight light-dimmer

25 controlling unit 3323 and the blink controlling unit 3324.

In the example illustrated in FIG. 49, the final liquid crystal luminance waveform has become the

waveform resulting from superimposing the blink wave-
form by the blink controlling unit 3324 on the light-
dimmer waveform by the backlight light-dimmer control-
ling unit 3323. In contrast to this, in the present

5 example, the control over the light-dimmer waveform by
the backlight light-dimmer controlling unit 3323 is not
executed. Instead, the light-dimmer waveform is always
maintained in the maximum luminance state, and the
light-dimmer control corresponding to the luminance

10 distribution detection data is executed together with
the blink control by the blink controlling unit 3324.
Namely, the control signal from the backlight light-
dimmer controlling unit 3323 is controlled so that the
output pulse duty always becomes equal to 100 % from

15 the light-dimmer characteristic diagram in the inverter
board 3103 illustrated in FIG. 48. Next, the blink
controlling unit 3324, as the example of improving the
motion-frame picture blur, sets the target onto the
lower screen portion of the display screen, then

20 performing the control so that the blink waveform is
switched ON in the latter-half of the 1-frame. More-
over, the blink controlling unit modifies the pulse-
width of the blink waveform in correspondence with the
state of the luminance distribution detection data. In

25 the example in FIG. 52, the image data are inputted in
the order of "the bright image → the dark image → the
bright image". Consequently, the pulse-width of the
blink waveform is widened for the bright image in the

next frame, and the pulse-width of the blink waveform
is narrowed for the dark image in the next frame.
Furthermore, in the example in FIG. 52, the blink
pulse-width in the backward edge of the pulse is fixed,

5   and the modification of the blink pulse-width duty is
executed in the forward edge thereof. As a result,
assuming that the time needed for the 1-frame time-
period is equal to "a" and the time during which the
blink waveform is kept ON in the latter-half of the 1-

10 frame is equal to "b", the blink waveform duty ratio
becomes equal to a ratio of "b : a", which is varied in
correspondence with the luminance distribution detec-
tion data. Also, according to the present example,
only the backlight ON/OFF control suffices as the

15 interface for the inverter board 3103. Accordingly, it
can be said that the present controlling function has a
general versatility.

        FIG. 53 illustrates another example that
differs from the examples illustrated in FIGS. 49 and

20 52 of the luminance control and the motion-frame
picture blur improving control by the backlight light-
dimmer controlling unit 3323 and the blink controlling
unit 3324.

        In the example illustrated in FIG. 53, in

25 contrast to the example illustrated in FIG. 52,
concerning the modification of the blink pulse-width
duty for the blink waveform controlled in accordance
with the luminance distribution detection data, the

blink pulse-width in the forward edge of the pulse is fixed, and the modification is executed in the backward edge thereof. Namely, in FIG. 53, the blink control-ling unit 3324, as the example of improving the motion-

5   frame picture blur, sets the target onto the upper screen portion of the display screen, then performing the control so that the blink waveform is switched ON in the former-half of the 1-frame. Moreover, the blink controlling unit modifies the pulse-width of the blink

10   waveform in correspondence with the state of the luminance distribution detection data. The blink pulse-width in the forward edge of the pulse is fixed, and the modification of the blink pulse-width duty is executed in the backward edge thereof. As a result, as

15   is the case with the example illustrated in FIG. 52, assuming that the time needed for the 1-frame time-period is equal to "a" and the time during which the blink waveform is kept ON in the former-half of the 1-frame is equal to "b", the blink waveform duty ratio

20   becomes equal to a ratio of "b : a", which is varied in correspondence with the luminance distribution detec-tion data. Also, in the present example as well, only the backlight ON/OFF control suffices as the interface for the inverter board 3103. Accordingly, it can be

25   said that the present controlling function has a general versatility.

FIG. 54 illustrates another example that differs from the examples illustrated in FIGS. 49, 52,

and 53 of the luminance control and the motion-frame
picture blur improving control by the backlight light-
dimmer controlling unit 3323 and the blink controlling
unit 3324.

5   The present example has both of the examples
in FIG. 52 and in FIG. 53. Namely, in FIG. 54, the
blink controlling unit 3324, as the example of improv-
ing the motion-frame picture blur, sets the target onto
the central screen portion of the display screen, then
10 performing the control so that the blink waveform is
switched ON in the intermediate region of the 1-frame.
Moreover, the blink controlling unit modifies the
pulse-width of the blink waveform in correspondence
with the state of the luminance distribution detection
15 data. The modification of the blink pulse-width duty
is executed both in the forward edge of the pulse and
in the backward edge thereof. As a result, as is the
case with the examples illustrated in FIGS. 52 and 53,
assuming that the time needed for the 1-frame time-
20 period is equal to "a" and the time during which the
blink waveform is kept ON in the intermediate region of
the 1-frame is equal to "b", the blink waveform duty
ratio becomes equal to a ratio of "b : a", which is
varied in correspondence with the luminance distribu-
25 tion detection data. Also, in the present example as
well, only the backlight ON/OFF control suffices as the
interface for the inverter board 3103. Accordingly,
the present controlling function has a general

versatility.

FIG. 55 illustrates another example that differs from the examples illustrated in FIGS. 49, 52, 53, and 54 of the luminance control and the motion-

5 frame picture blur improving control by the backlight light-dimmer controlling unit 3323 and the blink controlling unit 3324. In the above-described respective embodiments, when focusing an attention on the improvement of the motion-frame picture blur, the

10 addition of the light-dimmer control has made the liquid crystal luminance waveform differ from the blink waveform. For example, in the example illustrated in FIG. 49, an OFF time-period that accompanies the light-dimmer control has existed in the ON pulses of the

15 blink waveform. In the examples illustrated in FIGS. 52 to 54, the light-dimmer control has changed the ON pulses of the blink waveforms set in the particular positions within a 1 screen in order to improve the motion-frame picture blur.

20 The example illustrated in FIG. 55, which improves these changes in the ON pulses, controls a backlight tube current as the light-dimmer control. Namely, concerning the improvement of the motion-frame picture blur, as is the case with the example illus-

25 trated in FIG. 49, the target is set onto the lower screen portion of the display screen, and the control is performed so that the blink waveform is switched ON in the latter-half of the 1-frame. Namely, in FIG. 55,

assuming that the time needed for the 1-frame time-period is equal to "a" and the time during which the blink waveform is kept ON in the latter-half of the 1-frame is equal to "b", the blink waveform duty ratio

5   becomes equal to a ratio of "b : a", which will be fixed in the present example. Concerning the light-dimmer control, if the luminance distribution detection data is judged to be of the bright image signal, the tube current quantity for the backlight is increased in

10   the next frame, thereby enhancing the luminance. Also, if the luminance distribution detection data is judged to be of the dark image signal, the tube current quantity for the backlight is decreased in the next frame, thereby lowering the luminance. Based on the

15   light-dimmer control by the backlight tube current quantity in accordance with the luminance distribution detection data, the present control makes it possible to fix, in whatever cases, the blink waveform for improving the motion-frame picture blur. This condi-

20   tion allows the stable motion-frame picture blur improving effect to be always obtained with respect to a particular region on the display screen.

     The embodiments in the present invention allow the high-display-quality motion-frame picture

25   display that exhibits the excellent light-emission efficiency and uniformity at a high-luminance of the lamps in correspondence with the movement speed of the image data.

Moreover, the embodiments in the present invention make it possible to change, in real time, the dynamic range in correspondence with the tone characteristic of the image data. This allows the

5 high-display-quality motion-frame picture display that exhibits the excellent light-emission efficiency and uniformity at a high-luminance.

The present modes control the light-emission point-in-time or time-period of the light-source in

10 correspondence with the movement amount or the luminance of the displayed image. This results in an effect of enhancing the luminance of the displayed image with a high-efficiency and suppressing the heat-liberation from the light-source.

15 Also, the present modes control the light-emission point-in-time or time-period of the light-source in response to the luminance of the displayed image and the response characteristic in the liquid crystal portion. This brings about an effect of

20 improving the motion-frame picture blur.

Also, the present modes control the input/output tone characteristic in response to the luminance of the displayed image. This brings about an effect of enhancing the contrast.